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TROPICAL SUNLIGHT[1]

By Dr. PAUL C. FREER

LATELY DIRECTOR OF THE BUREAU OF SCIENCE, MANILA

THE subject of the influence of sunlight in the tropics has been the subject of extended discussion for many years, and the general opinion seems to be that the intensity of insolation is the most important factor influencing the physical welfare of the white inhabitants in those parts of the world lying within the regions which are generally considered as having a tropical climate. In considering the question of what may be regarded as a tropical climate, we are too apt to be influenced by preconceived opinions as to what the dominating factors are, and we are prone to lose sight of the fact that there is as much difference between tropical climates as between those in the temperate zones.

Persons living in the tropics are almost certain, during their early years of residence, through ignorance or otherwise, radically to change their mode of living and subject themselves to hygienic conditions which they would consider inadmissible in their former homes. The races of people native to the tropical zones have no knowledge of bacteriology and pathology which would enable them to understand the measures to be taken to avoid infectious and other diseases, whereas they live in regions where the absence of a pronounced winter is favorable to the rich development of microscopical life. As a consequence, many of the ill effects which are attributed to sunlight may in reality be due to entirely different causes. Again, races native in the tropics, as a rule, do not have access to the complete food supplies of persons in temperate

[1] The manuscript of this article was received by the editor two weeks after the cabled announcement of the lamented death of Dr. Freer. Dr. Freer had attained high distinction as a chemist and since taking charge of the scientific work of the government in the Philippines in 1901, had contributed greatly to the organization and advancement of the scientific work under our government.

zones, although this statement may sound paradoxical, and this fact in turn may morphologically modify the peoples to a greater extent than other influences.

It can readily be understood that a place recognized to be within the tropics, may, by reason of its proximity to the sea, its altitude, relation to mountain chains, and other natural surroundings, have a climate so modified that the actual sunlight may have less influence than in localities which may be situated upon the borders or even within the temperate zones. Another factor influencing local conditions may be the color of the soil and the resulting modification of the intensity of the heat rays coming from it, because the radiation from the soil is of importance.

In other words, pronounced differences may be found between the climates of two places in the tropics which may geographically be close together, as may readily be seen by comparing the meteorological data from Alexandria, Cairo and Aswan, in Egypt. Prevailing winds may so modify the climate of a region that during the nights the temperatures may closely correspond to those found in places more favorably placed. Indeed, in comparing two regions we may find the anomaly that the tropical situation, for long periods, may have a more temperate climate than is found at the place nominally lying outside of the zone in question.

The general trend of the discussion in the literature has been that the rays of the sun lying in the region of the spectrum comprising the violet and ultraviolet are of the greatest importance in determining the influence of insolation upon human beings, and these rays have a special, though undeserved, designation as actinic rays. Studies of the influence of these rays have not been lacking; it has clearly been shown that they are destructive to great classes of microorganisms, and methods have also been devised to measure the relative proportion of these rays as compared with other parts of the spectrum. However, no thoroughly systematic work in this line has been carried out, and comparisons in the tropics are decidedly lacking.

Therefore it seems evident that the entire question of the influence of insolation upon the inhabitants of the tropics exists as a legitimate field for experimental study and that comparative data from different regions may be obtained so as to solve many of the questions in an impartial manner. The Bureau of Science at Manila is very fortunately situated in regard to this work. Its equipment is ample and the composite nature of the staff makes it possible to carry it on in a number of lines simultaneously. In addition, the newly organized University of the Philippines offers opportunity to call upon the faculty of that institution for cooperation. The opportunity being at hand, it seemed advisable to begin cooperative work on the subject of tropical sunlight,

and, therefore, about three years ago, several members of the staff from the two institutions undertook different lines of investigations with the object ultimately of coordinating the results into a monograph on the subject.

The first problem was to obtain data regarding the relative influence of the rays of shorter wave-length on different days and in different latitudes; and to obtain reliable figures, it was necessary to determine upon the photocatalytic reaction to be used. The decomposition of oxalic acid in the presence of uranyl salts, which is brought about almost entirely by the rays in the spectrum of the sun extending from 550 $\mu\mu$ to 291 $\mu\mu$, was decided upon. Although this method is not free from grave objections, which have been pointed out by me in another article,[2] nevertheless extended experimentation brought the decision that it was best adapted to the ends sought. Having decided upon the method and thoroughly learned the factors which influence the reaction, cooperation was requested in a number of laboratories in various parts of the world. The returns have not all been received, but so far extensive comparative measurements have been conducted in Manila (latitude 14° 36′), Kuala Lumpur in the Straits Settlements (latitude 3° 10′), Honolulu (latitude 21° 10′), Washington (38° 59′), Khartoum, Egypt (latitude 14° 36′), and a few data have been obtained from Tucson, Arizona (latitude 32° 12′). As yet, the returns from a number of other places have not been received. The results are surprising. In each one of the localities mentioned above, days of maximum insolation were observed which were practically identical, and in a number the averages were very close together. So, for example, at Manila the average percentage of oxalic acid decomposed for one hour during one year was 12.45; at Kuala Lumpur, 11 degrees farther south, 15.29; at Honolulu, 7 degrees farther north, 13.81, and at Khartoum in the Sudan, 17.6. The great differences do not lie in the averages obtained, but in the minimum observed on cloudy days. So, for example, both Kuala Lumpur and Khartoum show surprisingly uniform degrees of insolation, whereas in Manila and Honolulu the proportion of cloudy days is so great as to bring the average down materially. In Manila the minimum observed was 1.15; in Honolulu, 3.48; whereas at Kuala Lumpur the same figure was 9, and at Khartoum 14.7. Therefore, the difference of climate of these places is not due to geographical location, but is purely a meteorological phenomena. Washington, with a winter climate and presumably much greater atmospheric disturbances, on the entire average gave about 33 per cent. less decomposition than Manila, yet the maxima are practically the same and at times Washington shows an astonishingly high average, and there is but little difference between the summer and winter months in the latter place.

[2] *Phil. Journ. Sci.*, Sec. B. (1912), 7, 1.

As mentioned above, we have but few data from Tucson and, therefore, at present we can scarcely make a comparison, but doubtless when a longer series of observation is at hand we shall discover that there are many days in Tucson showing a maximum as high or even higher than Manila, and an average of about the same. The fact is also observed that two days apparently equally clear will show marked differences between each other during corresponding hours, so that the proportion of the rays reaching the earth and lying between 550 $\mu\mu$ and 291 $\mu\mu$ varies from day to day. A comparison of the total effect of these rays with the measurements obtained by the black bulb thermometer also demonstrates that the two are not functions of each other. Of course it is clear that there must be a certain relationship because, obviously, on clear days both black bulb readings and photocatalytic measurements will be high, but they need not necessarily be high in the same proportion. The sun's rays which lie in the portion of the spectrum under discussion, on reaching the atmosphere, suffer molecular scattering, refraction and other changes which modify the proportion of direct sunlight that reaches the earth's surface, and, of course, these changes vary with the condition of the atmosphere. Nevertheless, it is very interesting to observe that even in the tropics the shortest wave-lengths appearing in the spectrum of the sunlight are very close to 291 $\mu\mu$ and that no shorter rays reach the surface of the earth. The same observation was made in northern latitudes, so that it can confidently be stated that the range of the spectrum everywhere is the same, the difference, if any, being in the intensity of the light.

The average of the measurements made at Baguio, which lies a little north of Manila at an altitude of 1,432 meters, shows that the photocatalytic action of the sun in that locality is much the same as it is in the lowlands. The maximum is slightly higher, being practically identical with that of Honolulu, and the average is 1.75 per cent. more than in Manila, and 1.09 less than at Kuala Lumpur, and 0.39 more than Honolulu, so that the ascent of 1,432 meters has produced the same effect upon the photocatalysis as would a transfer from Manila to Honolulu.

The above is a very brief summary of the results so far obtained in a study of photocatalytic reaction brought about between the rays lying between 550 and 291 $\mu\mu$, and in view of the results the more extensive remainder of the spectrum, which extends upward from the point mentioned into the red and infra-red and which would include the heat rays, must be considered. It is self-evident that comparative measurements in this field involve much greater difficulties, as, at present, no photocatalytic reaction is available. The best means at hand is by a comparison of a series of readings with the Angström pyrheliometer of

the total solar radiation per square centimeter of surface normal to the ray of incidence.

Unfortunately, measurements in the tropics with this instrument are lacking and in Manila we have not yet been able to carry them out, because the instruments which we have ordered have suffered great delays in delivery. A large number of available data have been gathered by Dr. Herbert H. Kimball, of the Mount Weather Observatory, and comparisons of the maximum intensity of solar radiation extending from Cape Horn, on the south, to Treurenburg, on the north, show that the variations are not great and those which appear, in the belief of Kimball, are due to instrumental errors rather than to atmospheric conditions. Angström gave some measurements from Teneriffe (20° 30′ north) and obtained practically the same figures as those quoted by Kimball. Dr. Rudolph Schneider in February, in Vienna, found a maximum higher than that given for Cape Horn and practically the same as that at Katherinenburg, and the observations made by him for the time close to the noon hour show a close resemblance to those in Washington. Harvey N. Davis, of Providence, Rhode Island, obtained practically the same results. Kimball, in discussing the annual march of radiation, as compiled by him, states that "a rather surprising uniformity throughout the year (is shown) in the maximum intensity of radiation, the December minimum being only 8 per cent. less than the April maximum." Even if we take the annual total we find that Warsaw actually has 85 per cent. of the radiation received at Washington, although it is 20 degrees farther north.

Because data with the Angström pyrheliometer in the tropics were lacking, we had recourse to animal experiments in Manila. In this connection it should be remembered that although air temperatures in some regions may be low and in others high, the effect of the sunlight on solid objects, as in the case of the black-bulb thermometer, may be very great and bear no relation to the shade temperature; so, for example, Davos, Switzerland, shows an average maximum black-bulb thermometer reading for three years of 53°.8 with a highest absolute maximum of 67° in 1910, whereas the maximum in Manila in one year was 56° and at Helwan, Egypt, 70°.8 during a period of three years. Alexandria during the same period gave 57°, Aswan Reservoir in June, 1910, showed a maximum of 81°, and Ley, Thibet, with an altitude of 3,517 meters, a maximum black-bulb thermometer reading of 101°.7 with a shade temperature of 23°.9. These figures refer to maxima only and do not take into consideration averages or the shade temperatures which might be high or low, but it is evident that the occurrence of days of extreme insolation is not so much a matter of latitude as of situation and it is evident that even in the tropics we might come to averages decidedly lower than in certain more northern climates. It is obvious

that in any one of the places mentioned and which lies outside the tropics, a living body might encounter days in which it would be heated by solar radiation to a much greater extent than in the tropics, and the only question would be whether the possibility of cooling, such as low air temperature, low humidity, winds or other means would compensate to avoid the effects of such insolation.

Our studies were undertaken with animals having fairly well developed means of heat regulation. The most interesting results were obtained with monkeys and human beings. To obtain comparable data, means had to be devised to give accurate and rapid measurements of the temperatures of the skin and of the inner parts of the body, and eventually a very satisfactory apparatus was completed by Dr. Hans Aron, of the department of physiology of the College of Medicine and Surgery, which gave the temperatures by means of specially prepared thermocouples, the changes being read by a tangent galvanometer. Monkeys are naturally at home in the tropics, and we should suppose that they would best be able to withstand the effect of sunlight. They have a system of sweat glands, but this is not so highly organized as it is in man, so that their physical heat regulation is brought about not only by evaporation of sweat, but also to a very great extent by water evaporated from the lungs and mouth through increased respiration. If a monkey is exposed to the sunlight in Manila, his subcutaneous and rectal temperatures rise rapidly, the former more rapidly than the latter, and the animal will die within 1 hour and 20 minutes to 1 hour and 50 minutes, the temperatures gradually reaching maxima. Entirely different results are obtained if the animals are shaded, even by such a small area as is produced by an umbrella or a piece of board, all other conditions being similar, except that the direct rays are excluded. Under these circumstances the skin and rectal temperatures never exceed 40° and the animals remain healthy. Similar results are obtained if the animals are exposed to full insolation, but care is taken to conduct away the excessive heat increment by means of a brisk current of air from a fan. Under these circumstances the subcutaneous and rectal temperatures remain the same as when the animal is shaded. In this form of experiment the monkey is exposed to all the rays of the sun, including those of lesser refrangibility, heat waves alone being conducted away. If untoward effects are to be attributed to the absorption of the ultraviolet rays, then surely the animal is in the same condition to absorb the latter as he is when no blast of air is present, and their effect should be apparent. On absorption, a large proportion of these rays is presumably converted to heat and conducted away as such, so that it can be assumed that the effects which we observe on exposing these animals to the sun is one of heat, and these conclusions are borne out at autopsy where post-mortem examinations give protocols clearly

pointing to heat stroke. Monkeys enclosed in tight boxes, with only the heads exposed, and placed in the full sun, suffer no inconvenience, although the hair temperature on the scalp may reach 47°. Of course, it must be understood that the monkey's skin is protected by fur and is not sensitive to the irritating effects of the ultraviolet rays as would be the case with the skin of a Caucasian, who, if exposed to the sun, would be sunburnt, whether in a strong blast of air or not. This latter effect is due to the ultraviolet portion of the spectrum, and, as these rays have but little power of penetration, the skin can in time amply protect itself by pigmentation. But even though protected, as is the monkey's skin, and hence not subject to sunburn, the heat effect still remains and brings about the results of excessive heat exposure.

Experiments on man have shown that the ultraviolet rays are easily guarded against, by shade or even by a white cotton shirt, the heat rays not. In man we have a subject with highly developed sweat glands, so that the means of heat regulation by evaporation are much more complete than in dogs, rabbits or monkeys.

Skin temperatures of men in this climate in the shade under normal conditions, as measured by our apparatus, vary within the extreme limits of 31° to 34°. On exposure to the sun, these temperatures rise rapidly on the sunny side, but as soon as the human subject begins to sweat, even slightly, the temperature begins to fall, and with muscular exertion may be as low as 31–33°. If the subject is at rest, the skin temperatures do not fall as rapidly, but after one hour they may be the same as at the beginning of the experiment or even more than a degree lower. In going over our long series of figures we found that fifty minutes of exposure caused no practical rise over the temperatures after the first ten minutes in white men and in Malays.

The comparison showed but little difference between the white and the Malay, the difference, if any, being in favor of the latter, but a Negro, in a series of observations, exposed to the sun at the same time as a blond European and a brown Igorot, showed a higher skin temperature by 1°.45 than the Caucasian. At the end of the experiment the final temperatures were decidedly against the Negro, slightly against the Tagalog, and in favor of the white skin. Therefore, so far as they have gone, our experiments seem to show, as regards rise in temperature upon exposure to the sun, that the white and brown skins are about equal, with a slight factor in favor of the white, but that in the case of the very dark-skinned Negro the temperature, on exposure, reaches a decidedly higher point than it does with either of the others. The dark skin of the Negro obviously will absorb heat more readily than the lighter one of the European, and also will radiate more readily, the heat taken up on the sunny side being rapidly lost on the shady one; but this balance evidently results in a greater rise of temperature for

the Negro than for the white man. With the white skin we have the phenomenon of sunburn, with its resultant irritation of the nerve-endings and hyperemia of the peripheral tissues, and this will cause a rise which, apparently, just about offsets the rise in the pigmented brown skin due to the sunlight. To determine definitely the decided difference brought about by the color of the subjects, it was decided to use experimental animals which would show great contrasts; and white, gray and black rabbits gave the data sought. I will select one experiment. When exposed side by side to the sun, the black rabbit reached a maximum subcutaneous temperature of 47°.8 in thirty-one minutes and then died; the gray rabbit a final temperature of 44°.9 in one hour and twenty-six minutes and then died; the white rabbit a final temperature of 45°.7 and when put in the shade it recovered, although much exhausted. None of the animals suffer from sunburn as does the white man, and it is evident that the darker the coat, the greater the heat absorption and the more apparent do the effects of insolation become.

These experiments bring us to the conclusion that, all other things being equal, the Negro will suffer more from the heat effects of the sun than the lighter-skinned races, and all of the work tends to show that the rays of greater refrangibility in the violet and ultraviolet portions of the spectrum are not the important factors, except in so far as they cause sunburn and subsequent excessive pigmentation. However, protection from these rays is easily accomplished and has been accomplished so long as man has worn clothes. These experiments also show that the whiter the clothing the better it is adapted for protection against sunlight and that even in the tropics, if care is taken to seek the shade, no untoward effects can be observed. Indeed, Major W. P. Chamberlain, United States Army Medical Corps, who investigated the systolic blood pressure of a large number of residents in the Philippines, concluded that there is no progressive tendency for the pressure to increase or to decrease with a continued tropical residence covering periods of over three years, beyond which length of time his observations do not extend.

From all of our present studies it would seem legitimate to draw the conclusion that a climate such as we have in the Philippines, where we are surrounded by the sea which modifies the extreme of temperatures and where we have such a large proportion of cloud, is not by any means deleterious to the white man if he takes ordinary precautions which are not as elaborate as those he would take in a northern climate to keep out the cold. In the Philippines the nights are rarely too hot for comfort; they may even be quite cool.

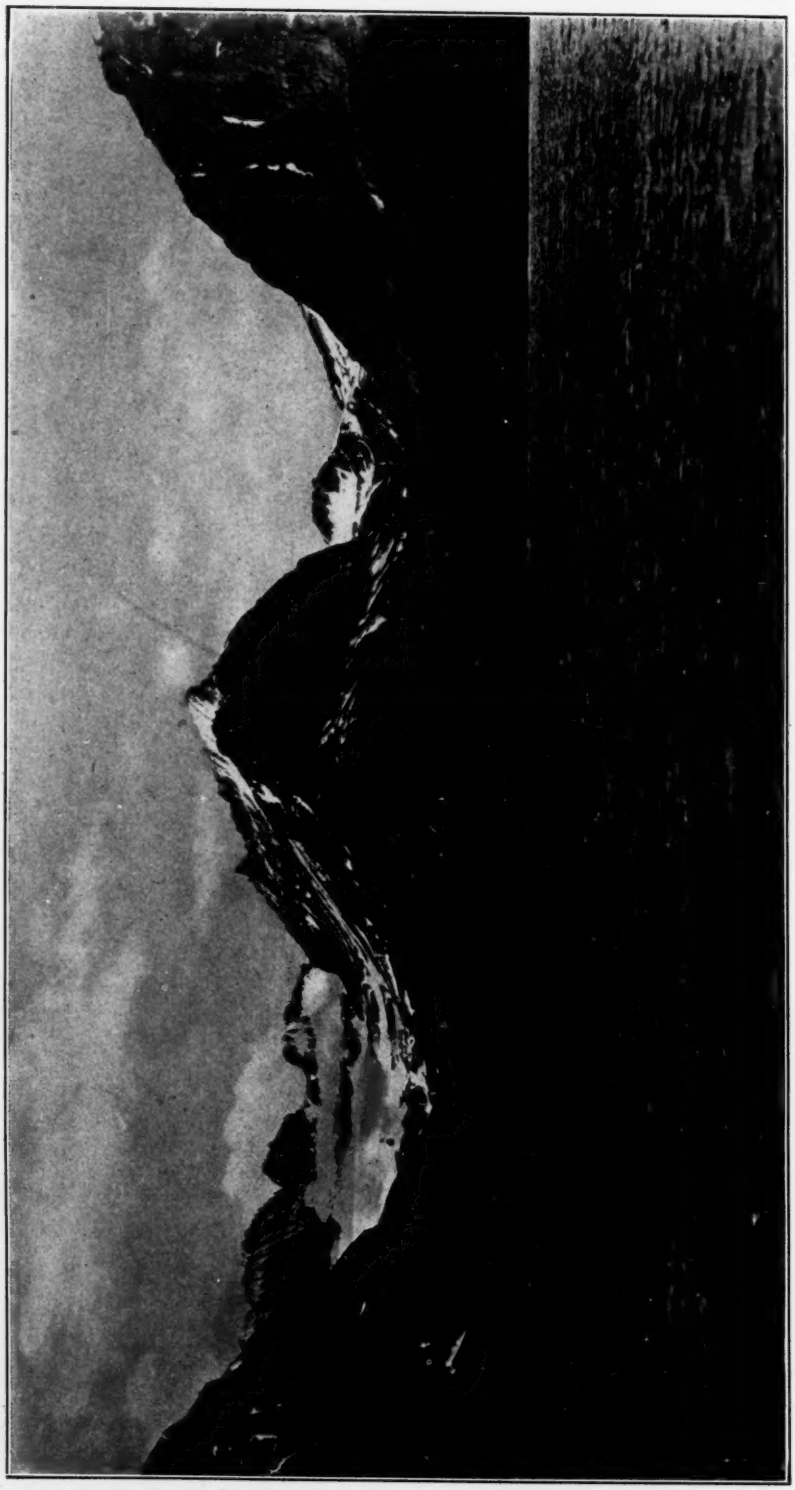
The actual number of hours of insolation per year on the earth's surface, were the sky always clear, is greatest at the equator and diminishes toward the poles, the ratio between 0° and 45° being 1.83 to 1.34,

although in the longer days in the temperate zone the sunshine reaching the earth when the sun is near sunrise or sunset is only a small proportion of that at midday. As a result we have in the tropics greater absorption and radiation from the earth's surface as a result of direct exposure to the sunlight to augment the influence of the sun's rays, so that, as it has been shown that the heat factor is the chief one to consider, this increment due to radiation from the earth will be of decided influence. This will naturally vary with different regions according to the hours and intensity of insolation and the color of the surface exposed, being least with green surfaces of vegetation and greatest with rocks, or red, clay soil, such as is common in India under the name of laterite.

Another factor needs to be considered, and that is the evenness of the tropical climate, which is devoid of severe contrasts, such as are given by the winters in northern climates, yet Chamberlain's results seem to indicate that this has but little effect.

I have endeavored in this short article to give a very brief résumé of the most important points which, up to the present, have been brought out. Any one can see that the subject under investigation is so complex and that it is influenced by so many factors that general conclusions at the present time are premature, excepting in so far as they are borne out by experimental evidence. Obviously relative humidity is of great influence on evaporation and varies with geographical locality, the season of the year, and other causes. Experiments carried on in Manila also seem to show that the Malay and the Negro possess relatively more sweat-glands than the European. The formation of ions in the air, the proportion of such ions, if any, due to the effect of the sunlight, and the total ionization brought about by radioactivity may be of influence in controlling the electro and other meteorological phenomena, and we have also begun work in this direction, but as yet are not in a position to publish the results.

Although the spectrum of the sun, as shown by the spectrograph, does not extend beyond 291 $\mu\mu$, still it may be possible that we receive rays the nature of which we have not yet determined and which, with our present physical technique, we can not determine. These may also be factors in the phenomena of insolation.



Photograph by Bailey Willis.

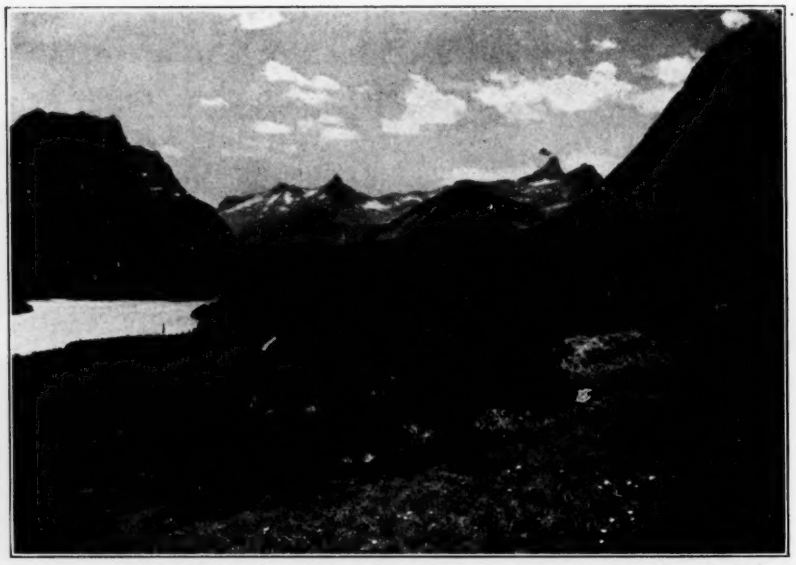
MOUNT SYPEH, SCENE UP CANYON CREEK, NEAR ALTYN, MONTANA. GLACIER NATIONAL PARK.

THE NATIONAL PARKS FROM THE SCIENTIFIC AND EDUCATIONAL SIDE

By LAURENCE F. SCHMECKEBIER
WASHINGTON, D. C.

THE passage of the act of Congress creating the first national park —the Yellowstone—was due in large measure to the interest and activity of the chief geologist of the Geological and Geographical Survey of the Territories, Dr. F. V. Hayden, and in the forty years that have elapsed since the creation of that great reservation the wonders of the national parks have claimed the attention of workers in every branch of science. As might naturally be expected, the more extensive scientific work in the parks has been in the field of geology and its allied sciences, because the wonderful forms of nature which have been the main factors in inducing congress to create these parks are the result of forces whose study falls particularly within the realm of geology. In the Yellowstone Park the geysers, the hot springs, the terraces, the fossil forests and the Grand Canyon of the Yellowstone River present absorbing and instructive geologic problems; in the Mount Rainier National Park is one of the largest glacial systems known to radiate from a single peak; in the Crater Lake National Park is the only lake in the United States that is situated in the caldera of an extinct volcano; in the Yosemite National Park the great gorge of Yosemite Valley presents perplexing problems to the student of physiography and widely divergent theories have been advanced regarding its origin; in the Glacier National Park are over 80 glaciers varying from a few yards to five acres in extent that have received practically no attention from the student of glaciology. But geology can not lay claim to the entire field. At the Hot Springs Reservation of Arkansas the healing waters are of great interest to the chemist and physician as well as to the geologist, and in the Mesa Verde National Park the remains of the vanished race of cliff dwellers offer a prolific field to the ethnologist and anthropologist. In the Yellowstone, Mount Rainier, Crater, Yosemite, Sequoia and General Grant Parks there is a prolific flora of native trees, flowers and grasses such as can be seen in few places in the west. In all the parks the protection of the game affords opportunity for the study of many faunal species that have been almost exterminated except in these reservations.

The scientific bureaus of the government and various learned societies have issued publications on the parks that are accessible to the



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HEAD OF LAKE ST. MARY, GLACIER NATIONAL PARK.

scientific traveler who knows where to look for data and who has access to the libraries in which these publications are deposited. But to

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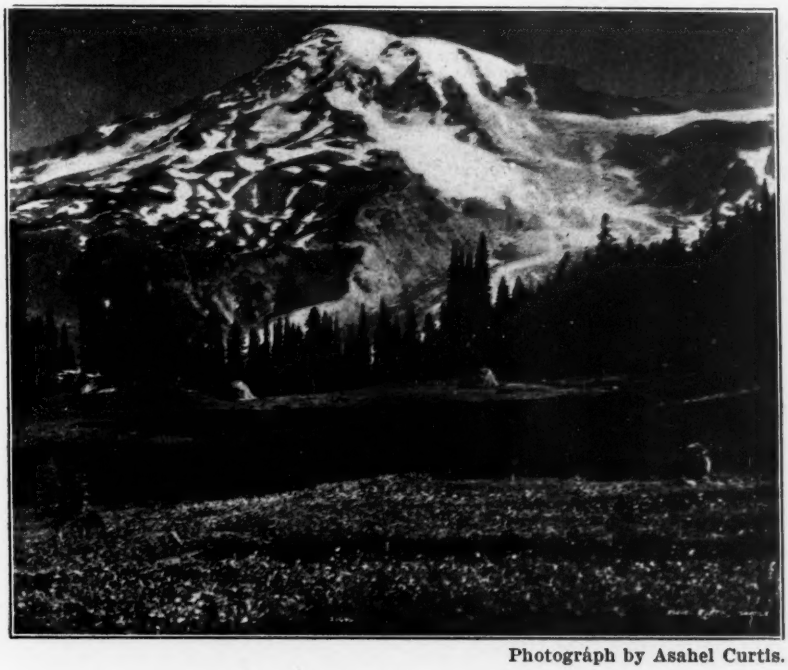
ICEBERG LAKE, GLACIER NATIONAL PARK.

the tourist or the teacher who does not have access to large collections neither the government nor the scientific societies have offered any assistance in his search for information. The publications either are not generally available or are so voluminous and technical that the general reader is repelled rather than encouraged to seek information.

During the season of 1911 over 90,000 persons visited the national parks, not including the visitors to the Hot Springs of Arkansas. The majority of these tourists are intelligent and educated people anxious to learn something about the causes underlying the wonders they are witnessing. Every one who has seen the beautiful and brilliant pools

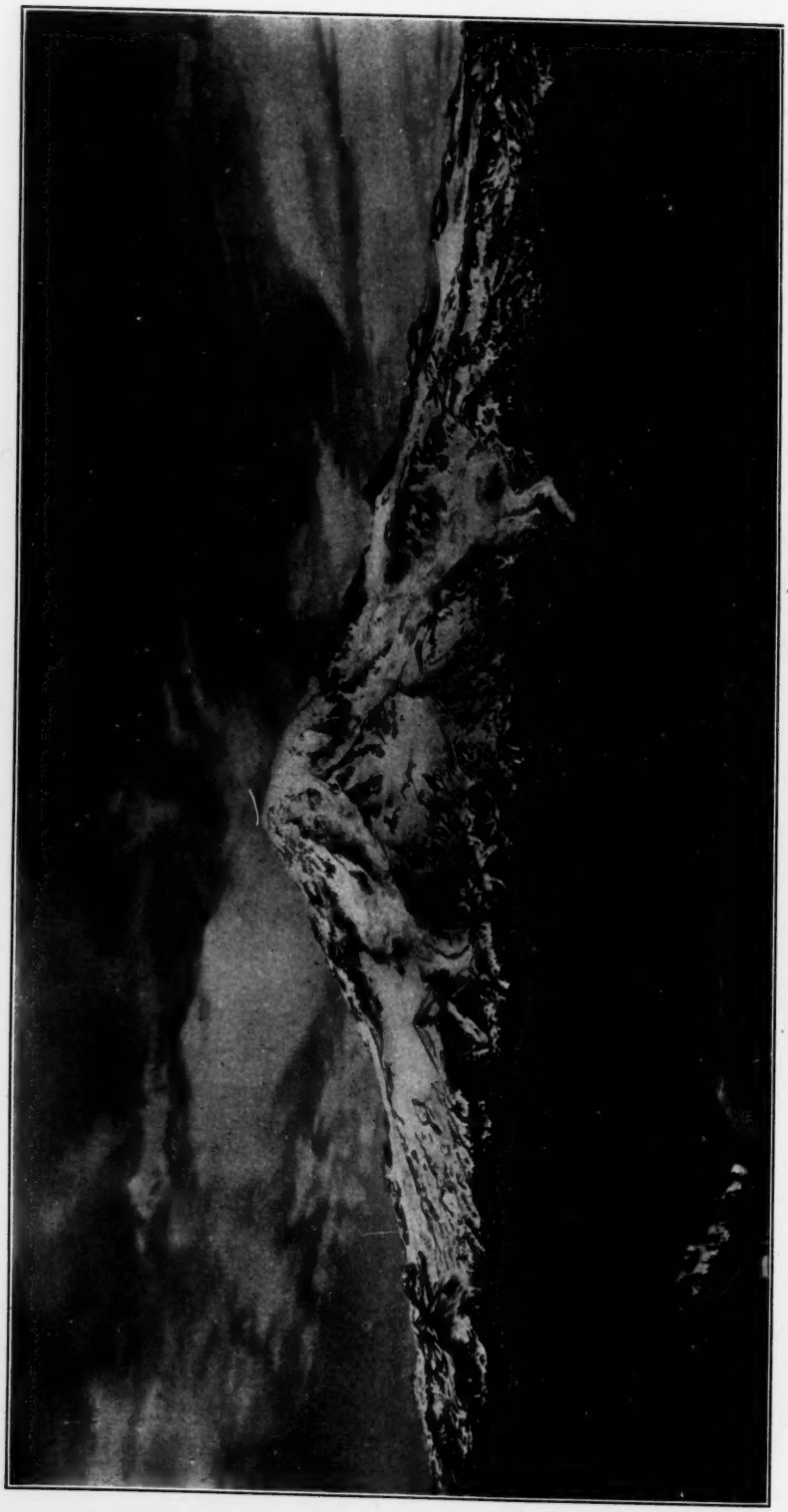


Photograph by Asahel Curtis.

PARADISE PARK AND MOUNT RAINIER.

in the Yellowstone Park is at least curious to know the cause of the harmonious and delicate coloring. The guides and stage drivers generally state that the colors are due to mineral matter, and as most people usually associate color with mineral the tourist goes home fully convinced, when as a matter of fact the color in the pools is due to the growth of algæ, as has been conclusively shown by Mr. Hague and Mr. Weed.

The officers of the Department of the Interior, which has charge of the national parks, have reached the conclusion that a series of short scientific publications on the parks will not only add to the pleasure of



Photograph by Asahel Curtis.

MOUNT RANIER, GAP POINT AND PARADISE VALLEY.

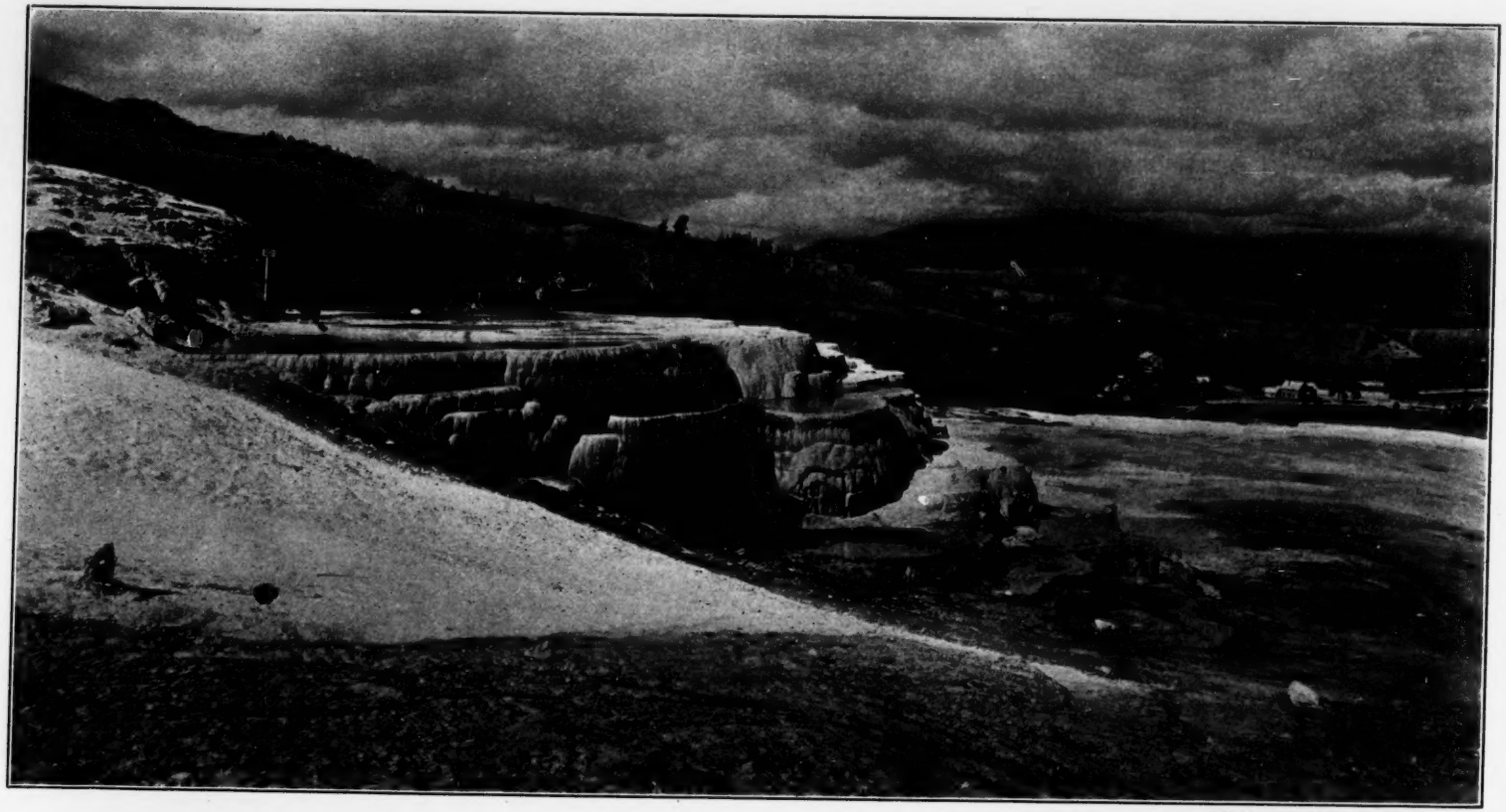
the tourist but serve an extremely useful educational purpose by disseminating the results of scientific work. It is therefore planned to issue a number of short publications describing the phenomena in the various parks and explaining the causes and forces that have produced them. It is not contemplated that the department will embark on original investigations, as it is believed that more material can be obtained than can be printed with the funds available, but it is hoped to revise some of the papers already published and issue them in pamphlet form. The department has just issued the following publications: "Geo-

Photograph by Asahel Curtis.

MOUNT RAINIER, FROM KAUTZ FORK. MOUNT RAINIER NATIONAL PARK.

logic History of the Yellowstone Park," by Arnold Hague; an account of the geysers of the Yellowstone Park, including a comparison with the geysers in New Zealand and Iceland, by Walter Harvey Weed, and the geologic history of Crater Lake, by Joseph S. Diller. These publications are illustrated with well-selected half-tones and carefully prepared black and white maps based on the accurate topographic maps issued by the Geological Survey.

The first need of the intelligent traveler is a map of the area he is about to traverse. Fortunately excellent maps of almost all the larger parks are for sale by the United States Geological Survey at nominal prices. Maps have been published of Yellowstone, Yosemite and Glacier national parks on a scale of 2 miles to the inch; of the Crater



Photograph by J. K. Hillers.

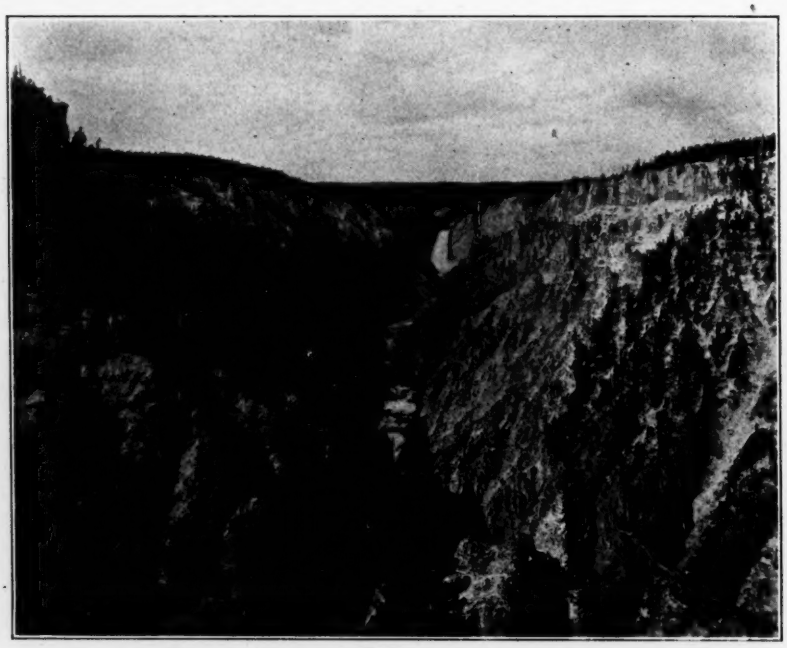
HOT SPRING, YELLOWSTONE NATIONAL PARK.

These terraces are composed of nearly pure travertine that has been deposited by the waters from the hot springs.

MOUTH OF FOUNTAIN GEYSER, YELLOWSTONE NATIONAL PARK.

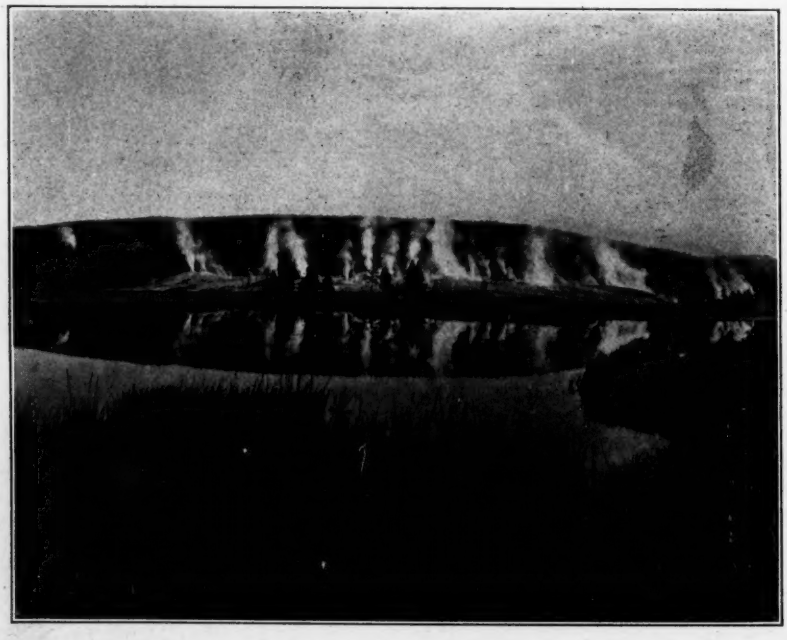
Lake Park on a scale of one mile to the inch and of Yosemite Valley on a scale of 2,000 feet to the inch. Separate maps of the Sequoia and General Grant parks have not been published, but the topography of these parks is shown on the regular atlas sheets issued by the Geological Survey. A part of the field work has been completed on the maps of the Mount Rainier and Mesa Verde national parks and the surveys will be finished during the coming summer. These maps should be ready for the season of 1913. All of these maps are in three colors, the drainage being shown in blue, the relief in brown and the culture or works of man in black. In addition the Department of the Interior has prepared tourist-travel maps of the Yosemite, Yellowstone, Glacier, Crater Lake, Sequoia and General Grant national parks. These maps will be in black only and will be used as double-page illustrations in

GLACIAL BOULDER, YELLOWSTONE NATIONAL PARK.

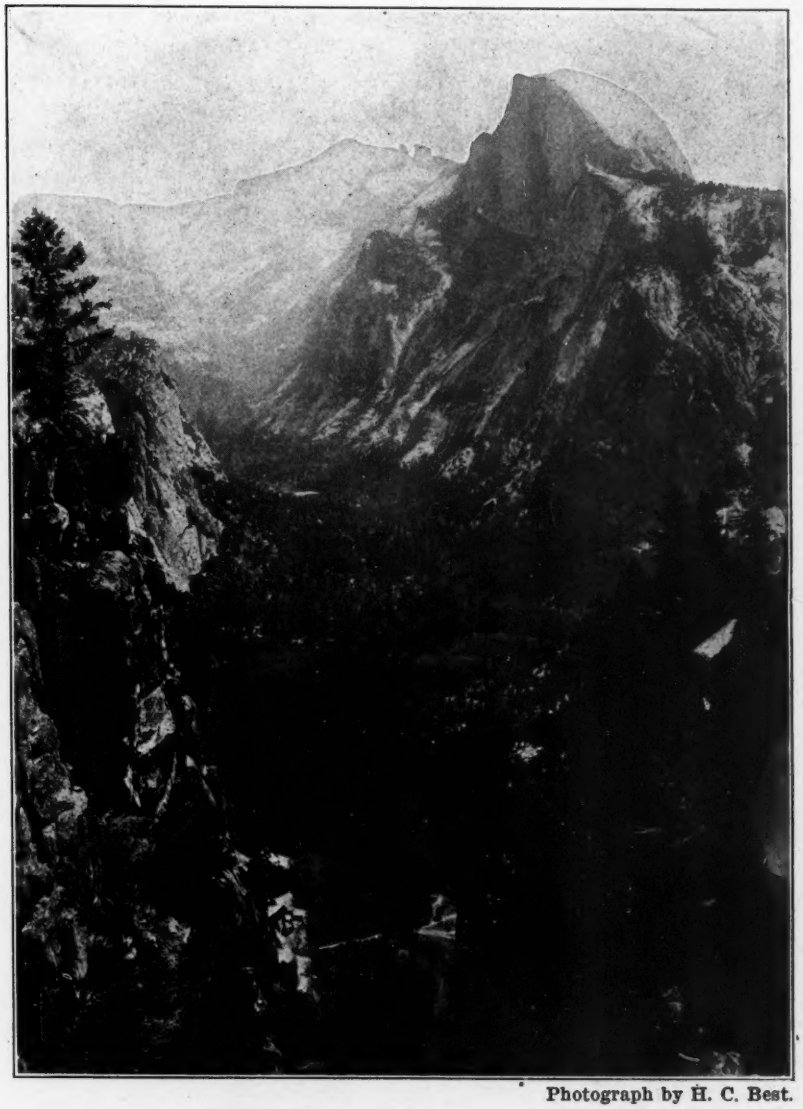


GRAND CANYON OF THE YELLOWSTONE.

some of the pamphlets in preparation. While they have been carefully prepared they are not intended to be substitutes for the more expensive and elaborate maps printed in colors.



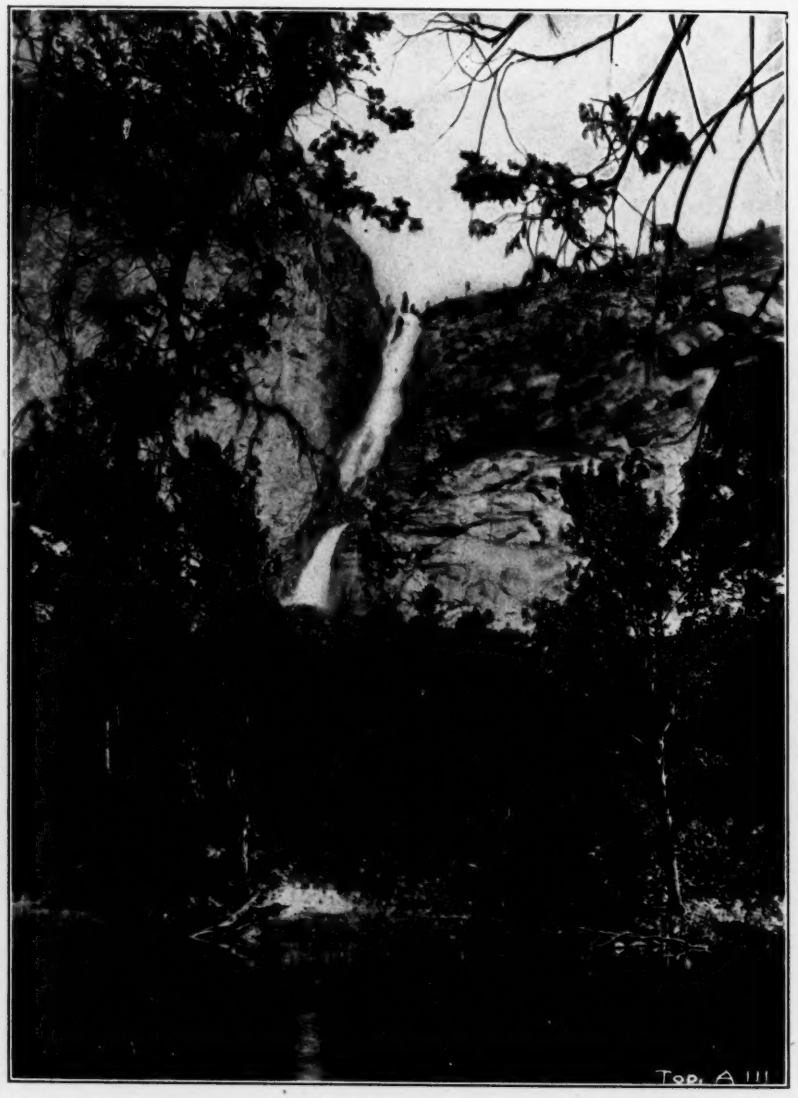
UPPER GEYSER BASIN, YELLOWSTONE NATIONAL PARK.



Photograph by H. C. Best.

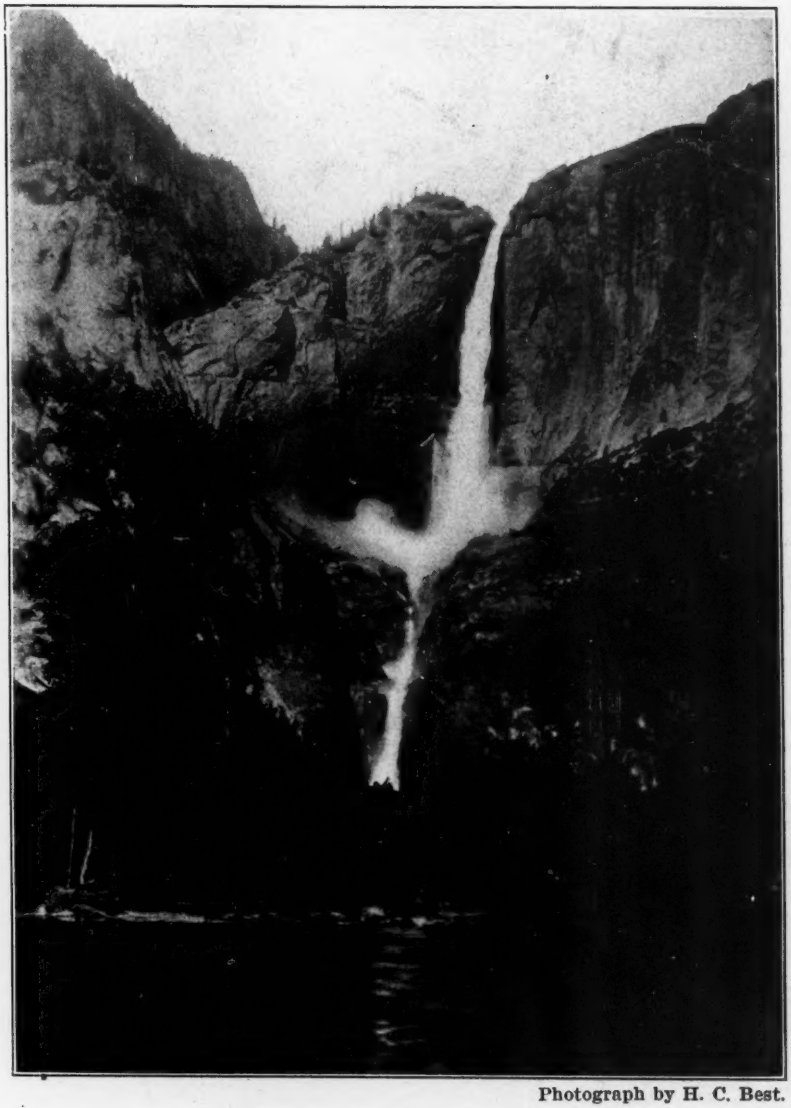
YOSEMITE VALLEY FROM MORAN'S POINT.

In addition to the descriptive articles it is proposed to issue short pamphlets on each park for the benefit of the traveler. These folders will give general information regarding the railroads tributary to the parks, the methods of transportation available within the parks, the location of hotels and camps, and the rates that are authorized for all classes of service. As the government does not operate any hotels, camps or stage lines in any of the parks, all these privileges being granted to corporations or individuals under term contracts or annual permits, this information will be published so that the traveler may intelligently plan his trip.



WAPAMA FALLS, south side of Tuolumne River, in the foreground Hetch Hetchy Valley, Yosemite National Park, Cal.

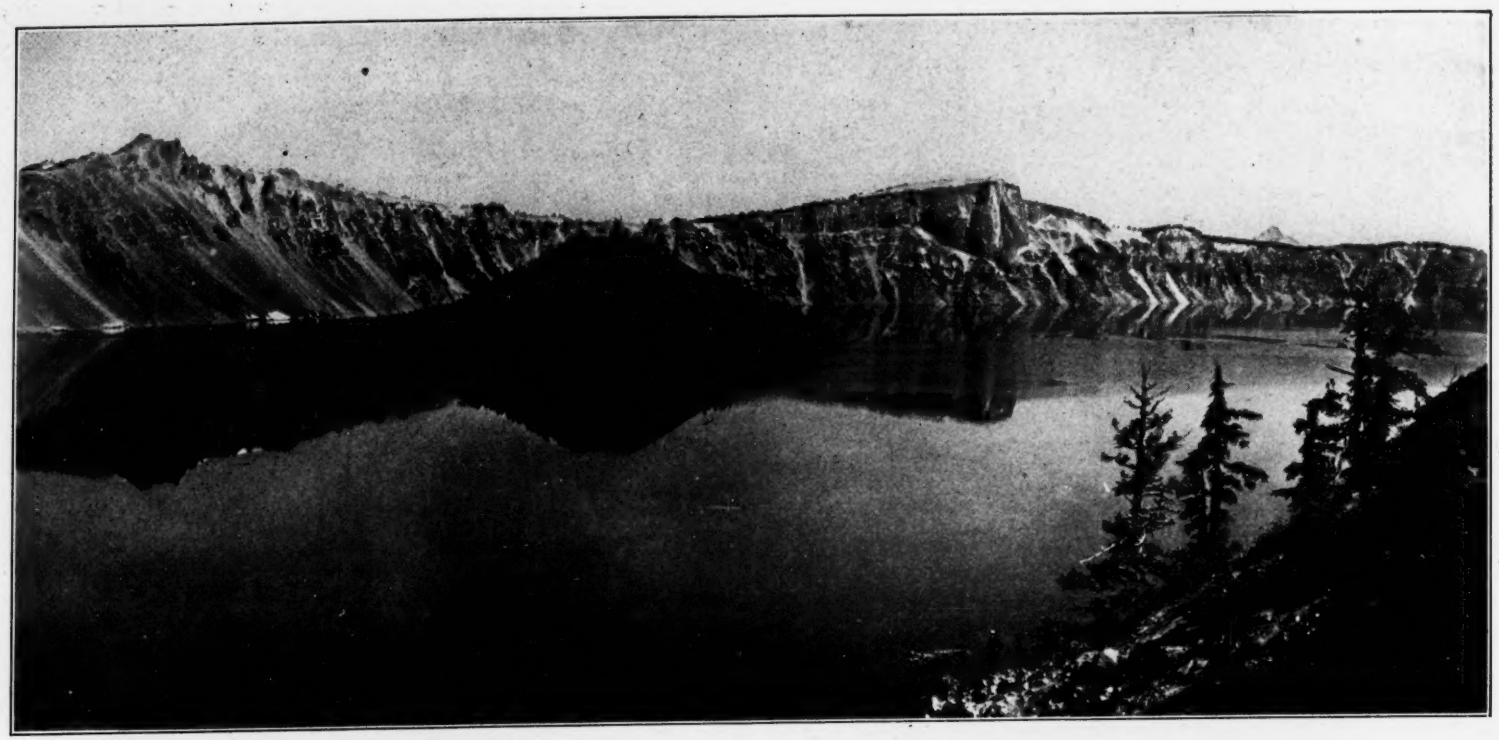
The question might well be asked why such work as this was not undertaken sooner by the government. The principal reason is that every officer of the government directing the affairs of the national parks is burdened with a mass of administrative details relating to other matters. The parks have been placed by law under the direct supervision of the secretary of the interior and the detailed administrative work is all done by officials immediately subordinate to the secretary. The Hot Springs of Arkansas were made a government reservation in 1832 and in 1872 the Yellowstone, the first of the great



Photograph by H. C. Best.

YOSEMITE FALLS. The upper fall is 1,430 feet; then come cascades, partly hidden, in which the fall is 675 feet, and finally a drop of 320 feet.

national parks, was created. Other parks were created as follows: The Yosemite, Sequoia and General Grant in 1890, the Mount Rainier National Park in 1899, the Crater Lake and Platt national parks in 1902, the Wind Cave National Park in 1903, the Sullys Hill National Park in 1904, the Mesa Verde National Park in 1906 and the Glacier National Park in 1910. Bills are now pending in congress for the creation of the Mammoth Cave National Park in Kentucky, the Peter Lassen, Mount Shasta and Lake Tahoe National Parks in California, the Mount Olympus National Park in Washington, the Saddle Mountain



CRATER LAKE, LOOKING NORTHWEST FROM VICTORIA ROCK. CRATER LAKE NATIONAL PARK.

This lake is situated in the crater of an extinct volcano. The upper portion of the mountain has collapsed, leaving the caldera.

Photograph by J. S. Diller.

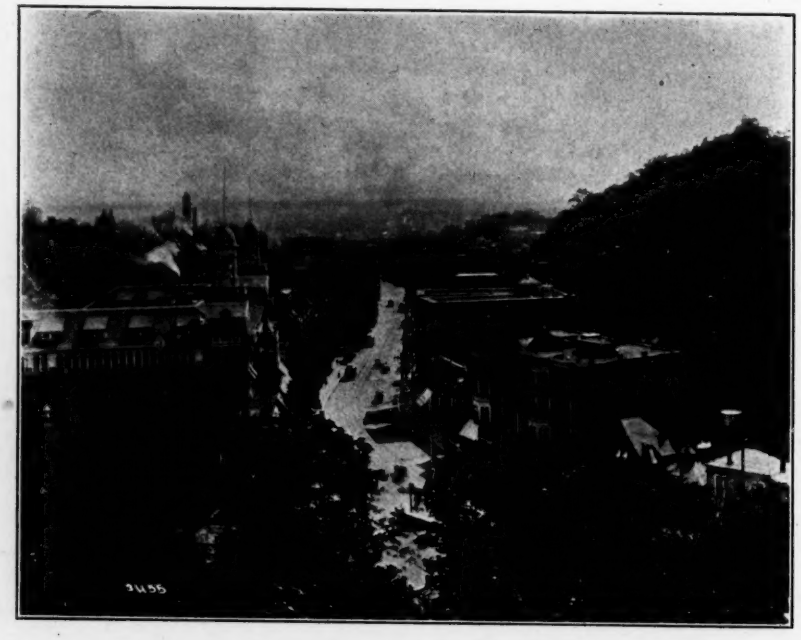
SOUTHERN SHORE OF CRATER LAKE.
From Castle Crest, Crater. The phantom ship is seen on the left.

Photograph by J. S. Diller.

WESTERN BORDER OF CRATER LAKE.

National Park in Oregon and the Rio Grande National Park in New Mexico. A bill was introduced in the last congress providing for the creation of the Grand Canyon National Park. The Grand Canyon now has the status of a national monument in a forest reserve. The creation of the following national parks has been advocated, but no bills have been introduced providing for them: The Kilauea National Park around the volcano of Kilauea in Hawaii and the Estes National Park in Colorado.

The secretary of the interior is also charged with the supervision of seventeen national monuments created by executive proclamation under authority of the act of congress approved June 8, 1906. This act au-



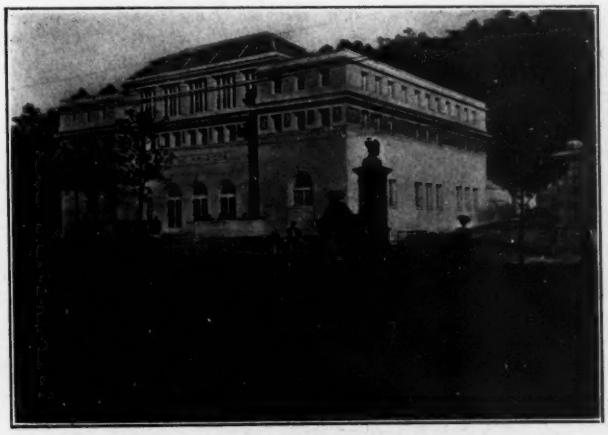
GENERAL VIEW OF THE CITY OF HOT SPRINGS.

thorizes the President "in his discretion, to declare by public proclamation historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest that are situated upon the lands owned or controlled by the government of the United States to be national monuments." The national monuments under the supervision of the secretary of the interior are as follows: the Devils Tower, a landmark in Wyoming; Montezuma Castle, Tumacacori, Chaco Canyon and Gran Quivira in New Mexico, and Navajo in Arizona—prehistoric or Spanish ruins; Muir Woods in California—a beautiful redwood grove presented to the government by William Kent; El Morro in New Mexico—a rock containing inscriptions made by the early Spanish explorers; Pinnacles in California—a group of spire-like for-

MOUNTAIN ROAD, HOT SPRINGS RESERVATION.

mations underlain by caves; Mukuntuweap in Utah—a peculiar and beautiful gorge; Shoshone Cavern in Wyoming and Lewis and Clark Cavern in Montana—limestone caves of great beauty; Natural Bridges and Rainbow Bridge in Utah—the four largest natural bridges in the world; Sitka in Alaska—the location of one of the earliest settlements and containing some of the finest totem poles known; Colorado in Colorado—an area of eroded monoliths similar to the well-known Garden of the Gods near Colorado Springs; Petrified Forest in Arizona —an area containing large deposits of silicified wood. Ten other national monuments are administered by the Department of Agriculture.

That the parks have been administered so ably and successfully is due to the faithful and devoted work of the officers in charge for many years. By much work beyond the regular office hours these officials have managed to attend to the pressing questions and the current busi-



ONE OF THE BATH HOUSES ON THE HOT SPRINGS RESERVATION.

BALCONY HOUSE, NORTH END, MESA VERDE NATIONAL PARK.

ness that have come before them. But there has been neither time nor energy for planning a series of publications such as have been outlined and it has been extremely difficult to make the limited beginning described above. The essential things have been done, but many desirable things have perforce been left undone.

Photograph by Arthur Chapman.

SPRUCE TREE HOUSE, CLIFF DWELLINGS, MESA VERDE NATIONAL PARK, COLO.

Photograph by Arthur Chapman.

CLIFF PALACE, MESA VERDE.

The number of visitors to the national parks has increased from 30,000 in 1906 to 93,000 in 1911. With this increase in the number of visitors the administrative problems have increased, and in order that national park affairs may receive the careful and detailed consideration they deserve, Secretaries Ballinger and Fisher have advocated the creation of a bureau of national parks. President Taft has warmly approved the proposal to create this bureau and in his message of February 2, 1912, referred to it as follows:

> I earnestly recommend the establishment of a bureau of national parks. Such legislation is essential to the proper management of those wondrous manifestations of nature, so startling and so beautiful that every one recognizes the obligations of the government to preserve them for the edification and recreation of the people. The Yellowstone Park, the Yosemite, the Grand Canyon of the Colorado, the Glacier National Park and the Mount Rainier National Park and others furnish appropriate instances. In only one case have we made anything like adequate preparation for the use of a park by the public. That case is the Yellowstone National Park. Every consideration of patriotism and the love of nature and of beauty and of art requires us to expend money enough to bring all these natural wonders within easy reach of our people. The first step in that direction is the establishment of a responsible bureau which shall take upon itself the burden of supervising the parks and of making recommendations as to the best method of improving their accessibility and usefulness.

One of the chief functions of such a bureau should be to arrange a series of publications that will deal clearly and in general terms with the geology, the botany and the zoology of these great reservations that are being administered by the government for the benefit of the people. The educational value of such a series of publications can hardly be estimated.

RESEARCH IN MEDICINE[1]

By Professor RICHARD M. PEARCE
UNIVERSITY OF PENNSYLVANIA

II. The Development of Laboratories for the Medical Sciences

IT would be interesting to trace in the events and activities of the later years of the eighteenth and early years of the nineteenth centuries that development of general thought which exerted indirectly an influence on modern medicine; but, under the circumstances, I can outline only a few; it was the period of the struggle for American Independence, of the French Revolution and of England's abolition of the slave trade. The world was becoming wiser and more humane; men and women were no longer hanged for witchcraft; the principle of education for all was being recognized; and it was also at this time that the insane were treated as persons ill of disease and not as prisoners, to be chained together and crowded into filthy pens until death should end their misery.

Captain Cook was enlarging the boundaries of the known world, Daguerre was establishing the art of photography, Murdoch was developing the use of coal gas as an illuminant, Watts was improving the steam engine, Fulton was concerned with the steamboat and Stephenson somewhat later with the steam locomotive. Machinery was being invented to replace hand labor, and advances in technical and industrial procedures were rapidly following one another.

It was likewise a period marked by the rise of great chemists and physicists, as Lavoisier, Scheele, Priestley, Avogadro, Dalton, Gay-Lussac, Davy, Volta, Franklin and Galvani; great naturalists as Cuvier, Humboldt and Lamarck; and great astronomers and mathematicians as Herschel and Laplace. At the time, the activities of these men were not seen to be directly contributory to the science and practise of medicine, but as the years went on and it became more and more evident—largely as the result of their work—that knowledge was to be gained not by establishing all-embracing systems of philosophy, but by the accumulation of facts through exact observation and experiment, their methods became the property of all branches of science and so, naturally, of medicine. In addition to method, moreover, these men offered, in the fruits of their labors, a not inconsiderable amount of data of

[1] The Hitchcock lectures, delivered at the University of California, January 23–26, 1912.

direct value to medicine, in the establishing of sound principles of physiology.

In the meantime, however, the practise of medicine labored under great difficulties and was largely a matter of empiricism. Without a knowledge of etiology, without pathological anatomy, that firm foundation for diagnosis, and without a rational therapy it could be nothing else. Mercury, cinchona, cathartics and bleeding were the general methods of treatment. Great and noble men filled the universities and hospitals; they labored conscientiously, and elaborated systems, and did what they could to relieve human misery, but to the advance of the science of medicine they contributed little or nothing.

Anatomy as a descriptive science dealing with adult structures and their gross appearance had been well established; but it waited for its fullest development upon the methods destined to establish histology and embryology. Experimental physiology, except as Haller and Hunter had influenced it, was an unknown field, soon, however, to be widely explored as the result of the introduction of instruments of precision and analytical methods. Pathology, dependent upon the methods of histology and physiology was marking time, and, in turn, internal medicine awaited the development of pathological anatomy. Surgery, slowly improving technical procedures, likewise marked time until anesthesia and asepsis opened new worlds to it.

The advance in these general subjects it is my intention to follow along the lines of physics, chemistry and biology, as they developed in France, England and Germany. And, if in the course of this presentation I have much to say about the work shops of these sciences, it is because universities, laboratories and hospitals, as well as societies and journals, represent the visible machinery of nineteenth century research in medicine, and whether we regard them as the cause or the effect of the awakening of 70 years ago, they to-day constitute our hope for the future of medical research.

It is difficult to select a starting point for a systematic survey. Chemistry, however, appears to promise the most direct course, for it was toward the end of the eighteenth century that Lavoisier introduced the modern scientific spirit of exact measurement as applied to chemical phenomena and through it established the great reform responsible for modern chemical knowledge and research. Carbonic acid had already been discovered by Black, hydrogen by Cavendish, nitrogen by Rutherford and ammonia by Priestley; oxygen had been studied by Priestley, Scheele and Lavoisier, so that with Dalton's atomic theory, Cavendish's analysis of the air and Lavoisier's study of oxidation, definite knowledge of the chemistry of air and water, and of combustion and respiration was at hand for the use of the physiologist and physiological chemist. At about the same time the science of crystallography

was established and somewhat later Davy's use of the electric current in the study of the alkaline earths.

In a word, activity in chemistry was evident everywhere, and theory and methods were being rapidly developed, but nowhere was chemistry a part of university study. Berzelius, Gay-Lussac and others had organized laboratories for the training of chemists, but it remained for the University of Giessen to establish the first chemical laboratory under the control of a university. Here, Liebig in 1826, when only 21 years of age, opened his laboratory and began his labors in organic chemistry.

The event is of importance, not only for chemistry, but for medical research in general, for the admission of chemistry to the university was the first step towards the overthrow of the "natur-philosopher" and hence to the development of that modern science which has made German universities so justly famous. It is also important from another point of view; in France science had been the work of the academicians, in England of workers in private laboratories or in those supported by commercial companies; by the new departure at Giessen, the precedent for university laboratories was established, and the world has since followed Germany's lead.

This laboratory of Liebig at Giessen was a success immediately and became the training school for most of the eminent chemists outside of Paris. The training offered at Giessen was systematic and methodical in qualitative, quantitative and organic analysis. In his autobiography, Liebig speaks of the difficulty "as the numbers increased, of the practical teaching itself" but "a progressive way of working" was thought out and tried, I can not refrain from quoting his own words concerning the development of the work in organic chemistry.

> The first years of my residence at Giessen were almost exclusively devoted to the improvement of organic analysis, and with the first successes there began at the small university an activity such as the world had not yet seen. . . . Every one was obliged to find his own way for himself. . . . We worked from dawn to the fall of night, there were no recreations and pleasures at Giessen. The only complaints were those of the attendant, who in the evenings, when he had to clean, could not get the workers to leave the laboratory.

In another place he says:

> I have found among all who frequent this laboratory (Giessen) for technical purposes a prominent inclination to occupy themselves with applied chemistry. They usually follow hesitatingly and with some suspicion my advice to leave alone all this time-absorbing drudgery, and simply to become acquainted with the necessary ways and means of solving purely scientific questions.

Such were the habits, the methods of work and the ideals of the man who in four years established that simple and accurate method of organic analysis known by his name. From his labors and those of Wöhler, who in 1828 announced the first synthesis of an organic sub-

stance (urea) dates our modern organic chemistry. Liebig representing the school of Gay-Lussac and Wöhler that of Berzelius, one at Giessen and the other at Göttingen, serve as an interesting example of scientific cooperation to develop a new science.

Liebig's work led directly to those activities which we now group under the term physiological or biological chemistry, but physiology was at this time making rapid strides along another line of attack—the application of the principles of mechanics and physics. The part of physics in medicine from Galileo to Roentgen is one of the most fascinating phases of the history of medicine; in principle and practise, in theory and science, its influence has been one of fundamental importance and in its application to methods of clinical diagnosis it shares equally with pathological anatomy in the awakening of modern clinical medicine. The first widely reaching application was in Harvey's interpretation of the circulation of the blood and the action of the heart, but it was not until organized physiological laboratories had been instituted that the application of the principle of physics bore abundant fruit. To recall the state of physics at that time it is only necessary to state that the work of Galvani and Volta was completed and that Ampère and Ohm, Faraday and Wheatstone, were still active. Charles Bell had already (1811) given to England the second of two great discoveries in physiology, the differentiation of sensory and motor nerves. Haller, as we have seen, had in the preceding century presented and discussed the irritability of muscle. The time was at hand for the study of the general physics of muscle and nerve and the special senses. Ernst Weber announced the principles of his psycho-physics in 1825 and Johannes Müller those of his physical chemistry in 1826; Purkinjé had already established the first university laboratory of physiology in 1824 at Breslau; in 1838 the celebrated physiological institute at Berlin was formed under the direction of Müller and in 1840 Ernst Weber was made professor of physiology at Leipzig. From these two centers, Berlin and Leipzig, from Johannes Müller and Ernst H. Weber, came a great volume of minute investigations based on exact methods of inquiry. Both schools were largely busied with studies of the mechanism of the perceptions of the senses, that of Weber tending to include mental phenomena, thus anticipating the modern school of psychologists, that of Müller including not only the methods of physics, but also those of general biology. Müller (1801–1858) was indeed the last of a school which attempted to embrace all of the territory of biology in its broad sense; a territory which now has its separate and distinct fields of morphology, physiology and chemistry. He may, however, be regarded as responsible for some of the divisions into which the older biology has been split, and for the impulse to new lines of study, for he was the teacher of the masters who came in time to occupy high places in biol-

ogy, of Schwann and Henle in anatomy, of Du Bois-Reymond and Helmholtz in physiology and of Virchow in pathological anatomy. It is not surprising therefore that it was the proud boast of this school that not only had it dispelled the vague notions of the old metaphysical school and established in its stead the true scientific spirit, but that it had filled so many of the chairs of medicine, physiology and anatomy in the German universities that the scientific spirit has been applied to "every branch of medical science, which it has in consequence drawn into the circle of the exact or mechanical sciences." (Merz.)

This is not the place to go into detail concerning the investigations of Müller and his school of physiology. His *law of "specific energies,"* Du Bois Reymond's electro-physiology and Helmholtz's work on musical acoustics and physiological optics indicate the character and scope of the work. The keynote of it all Müller himself has expressed in his "Elements of Physiology" as follows:

> Though there appears to be something in the phenomena of living beings which can not be explained by ordinary mechanical, physical or chemical laws, much may be explained, and we may without fear push these explanations as far as we can, so long as we keep to the solid ground of observation and experiment.

These principles and the labors of this school were advanced wonderfully, in 1847, by Ludwig's invention of the kymograph and the elaboration of methods of graphic registration, factors which established this phase of physiology on a sound basis and exerted an influence which medicine feels to this day. This, however, was not the only influence of Müller. As a biologist with general interests he stimulated general biological research and it was undoubtedly this influence exerted through Schwann that led the latter to grasp the importance of Schleiden's work on vegetable cells and to apply the observations of the latter to the cells of the animal body.

But although the cell doctrine, in its modern conception, is the result of the work of these two men, Schleiden and Schwann, it is not to be supposed that they were the first to study cells, for before Schleiden considerable attention had been given to the structure of vegetable tissues. Robert Hooke in 1665 had given to the spaces in cork and similar structure the names of "cells"; Malpighi (1674) and Grew (1683) had, as far as their low power lenses would allow, described plant tissue as made up in part of cell-like cavities provided with firm walls and filled with fluid, and in part of long tube-like vessels. Treviranus, in 1806, demonstrated that these tubes arose as the result of cells becoming attached end to end, the intervening ends eventually disappearing. The nucleus of the cell had been discovered in 1831 by Brown, who, however, failed to realize its importance. Not so Schleiden. He attached great importance to the nucleus and by the numerous observa-

tions (1839–1843) which he brought forward was able to formulate a definite cell theory for plants; later when this theory was applied to animal tissues and developed by Schwann and Virchow it became an influence as great as that of the theory of evolution, in the development of modern biology.

Schwann, who was at the time an assistant of Müller, received directly from Schleiden the impulse to compare animal and vegetable cells. While carrying out for Müller the experimental study of nerve and muscle, necessary for the proper preparation of his chief's great book on physiology, he became interested in the histological study of these structures and it was at this time that he described the nerve fiber sheath which now bears his name. Once, when he was dining with Schleiden in 1837, the conversation turned to the nuclei of vegetable cells, Schleiden's description of these recalled to Schwann similar structures which he had seen in animal tissues. The resemblance between the animal and plant cells was, without loss of time, confirmed by both observers and the result was Schwann's famous paper (1839) on the accordance in structure of animal and plant tissues.

It is difficult for the student of to-day, thoroughly drilled concerning the details of cell structure in his courses in normal and pathological histology, to realize that only a little over 70 years ago the essential feature of the animal cell, the nucleus, was not recognized, and that it was a botanist who first brought the subject to the attention of a physiologist. Medicine in all its phases has advanced rapidly along the path thus opened up by Schleiden and Schwann. To-day we are interested above all other things in the chemistry of the cell, but from the time of Schwann to the time of Pasteur the study of the morphology of the cell in health and in disease was one of the chief interests of scientific medicine.

It is not to be supposed, however, that Schwann had the conception of the cell which we have to-day. He, as Schleiden before him, made faulty observations and drew faulty conclusions. The important features of Schwann's work were the recognition of the nucleus, not the cell wall, as the important part of the cell, the demonstration of the union or grouping of the cells to form tissues,[2] and the demonstration that the distinctive cells of the tissues of the adult develop from the undifferentiated cells of the early embryo. The misconceptions of the early histologists were natural when we recall the great technical diffi-

[2] This statement does not disregard the work of Bichat (1771–1802), frequently called the "father of histology," to whom is due the credit of first recognizing the fact that the body was made up of distinct and differing tissues. Bichat's results, however, were obtained by the use of chemical reagents. He used the microscope but little, and his work, important as it was, and antedating the cell theory by 40 years, can not be considered as leading to the development of the cell theory.

culties with which they had to contend. The microtome, the microscope, and differential staining methods, in their present-day perfection did not exist for them. It was the day of the razor and hand sectioning. The first microtome appears to have been that used by Professor His in 1866; the improvements leading to the perfection of the present-day microtome did not begin until 1875. The development of the objective of the compound microscope was just beginning in Schwann's time (1830). Although iodine was early used, it was not until about 1857 that Geleach called attention to carmine, the first nuclear stain to be introduced into histological technic. At first, tissues were examined only in the fresh state and even later when hardened they were not imbedded as now in celloidin or paraffin, but placed between vegetable pith or blocks of amyloid organs during the process of cutting.

Surely the technical difficulties were great and we are not surprised that both Schleiden and Schwann believed new cells to be formed through a process of "crystallization" from a "mother liquor" or cytoblastema and that the cell was a vesicle with a solid wall. This question of minute structure and that of mitosis yielded eventually to improvements in technique and Schleiden's theory of the formation of cells *de novo* was discarded, and we know from Virchow's famous aphorism "*omnis cellula e cellula*" that in his time it was established that cells arose only by the division of preexisting cells. This general law was the result largely of the work of botanists, as Hugo von Mohl and Nägeli, and was applied by Virchow (1858) to animal tissues only after much work had been done on such tissues by Kölliker, Reichert and Remak. It was not until 1873 (Anton Schneider) that an insight into the details of cell division was gained and it was 1882 when the part of the nucleus in karyokinesis was satisfactorily demonstrated and Flemming could supplement Virchow's aphorism with another "*omnis nucleus e nucleo.*"

Thus did Schleiden, a botanist of the University of Jena, and Schwann, assistant (1824–1838) to Müller, establish one of the most brilliant and most important generalizations of the century, which became at once the basis of all morphological studies, and, as applied by Virchow, placed pathology on a scientific basis, and has continued as a result of its general biological applications—to development, inheritance and immunity—to influence medicine profoundly. As Verworn has said:

> It is to the cell that the study of every bodily function sooner or later drives us. In the muscle lies the problem of the heart beat and that of muscular contraction; in the gland cell resides the cause of secretion; in the epithelial cell, in the white blood corpuscle, lies the problem of the absorption of the food, and the secrets of the mind are hidden in the ganglion cell.

It will be necessary to return to the cell theory again in discussing

the development of pathology, but we may leave it for the moment to trace one other line of advance made by the physiologist; an advance in that phase of the subject which Du Bois Reymond characterized, in 1880, as "vivisection and zoochemistry" in contrast to the electrophysiology of nerve and muscle with which his own name is so closely linked, and in contrast also to the phase of physiology in which histology, following the lead of Schwann, was playing so large a part. This third field in physiology necessitates a shift of scene to France and Claude Bernard and his school and the study of the functions of organs and their secretions.

Claude Bernard (1813–1878) was the pupil and successor of Magendie. Magendie did many things, but best of all he made "the experimental method the corner stone of normal and pathological physiology and pharmacology." (Welch.) By this method he demonstrated, as Charles Bell had divined, the essentially different functions of the anterior and posterior roots of spinal nerves. Also he founded a journal of experimental physiology.

Bernard, departing widely from Magendie's work, followed in his researches one main idea, the action of the nervous system on the chemical changes which constitute the basis of nutrition and this problem he attempted to solve by either direct experimental investigation of nerves, or by chemical researches or by a combination of both methods. His most important discoveries were the demonstration (1) of the significance of the pancreatic juice in digestion; (2) the glycogenic function of the liver and (3) the vasomotor system. These investigations (1850–1860) with those of Ludwig (1851) on the mechanism of the secretion of the glands, with the earlier observation on gastric digestion made by our own countryman, William Beaumont (1833), and the discovery of pepsin by Schwann (1835) represent the principles out of which our present conception of the physiology of digestion has developed. Not only did Bernard make discoveries and work out the lines of progress for the study of the outward or external secretions of glands, but as a result of his study of the influence of the liver on carbohydrate metabolism, he formulated the theory of "internal secretions," which represents a field of physiology cultivated in the past few years with the greatest success and still full of promise for the future.

Bernard has the distinction of being the first man of science to whom France accorded a public funeral, a recognition not alone of personal worth, but also of the nation's debt to science and to research in the field of medicine.

Thus far I have presented the beginnings of those branches of medicine which deal with normal structure and function. Next in order of development comes that science which is concerned with the study of disease, pathology and upon which are based sound diagnosis and

rational therapy and for this reason the science of most interest in medicine. Pathology owes its position as a recognized science to the genius of Virchow, but, in its development, it also owes much to the period I have just discussed, as I will show in due time. To present this development properly it is necessary to turn back to 1761 and Morgagni. I must again remind you that in Morgagni's time medical science can hardly be said to have existed. It was the period of a vague philosophy which attempted to systematize diseases according to symptoms, with no reference to the anatomical conditions causing the symptoms. It was Morgagni who first insisted that the clinical history should be set side by side with the results of the autopsy and who by his publication "De Sedibus et Causis Morborum" threw the first gleam of light on the causes and nature of diseased processes, and thus gave a stimulus to the study of pathological anatomy. Before Morgagni's time, and for some time after, pathological anatomy was mainly concerned with the recording of the rare and curious, with malformations and obvious departures from the normal type; observations oftentimes interesting, but not systematized or harmonized. Morgagni is responsible for the maxim that observations should be "weighed not counted," and it was undoubtedly this point of view which influenced his observations and led eventually to the doctrine that most diseases were to be explained by changes in the organs of the body.

Another step in advance was taken when Bichat, about a quarter of a century later, referred disease to the tissues of the organs. In the meantime John Hunter (1728–1793) had applied to the problems of clinical medicine methods which we now recognize as those of experimental pathology. Still pathology was not a science; it was not systematized and it had no underlying principle. The systematization of pathological anatomy came through Rokitansky[3] (1804–1878) and the underlying principle of pathology from Virchow in 1858.

Rokitansky, the father of pathological anatomy, was an assistant to Johann Wagner, later succeeding him in 1834 as prosector and finally in 1844 as professor of pathological anatomy at Vienna. Wagner had encouraged the application to pathology of the methods of anatomy, and the publication of Rokitansky's "Handbuch der pathologischen Anatomie," completed in 1846 (one year before Virchow's "Archiv" was founded), presented to the profession the results of a most thorough study of the details of pathological anatomy. It is said that Rokitansky performed, as the basis for his classifications, more than thirty thousand autopsies. His position in pathology has been likened to that of Linnæus in botany. "Even to-day nothing can equal the accuracy of Rokitansky's observations. There are few things he did not see. When some lesion or combination of lesions seems entirely

[3] A worthy predecessor of Rokitansky was Johann Fr. Meckel, whose "Handbuch d. patholog. Anatomie" was published at Halle in 1804, the year of Rokitansky's birth.

new, it is often only necessary to go back to the work of Rokitansky to find that he had observed and accurately described it." (Councilman.) Although he encouraged the development of pathological histology, pathological chemistry and experimental pathology, he took no active part in these subdivisions of pathology and used the microscope but little. He seems to have been content with the establishment of pathological anatomy as a descriptive science.

Between Rokitansky's work and Virchow's cell theory there is no obvious connection. Between Morgagni, Bichat and Virchow we have an interesting link, that formed by the successive theories which placed disease in the organs, the tissues and the cell, respectively. Rokitansky worked with the organs and tissue and had no influence in carrying the quest on to the cell. The influences which led Virchow to the latter are wholly those we have discussed in the story of physiology and its beginnings, the personal influence of Johannes Müller, Schwann's writings and the results of the application to medicine of the methods of physics and chemistry. That he appreciated the importance of the relations of pathology, on the one hand, to physiology, and on the other to clinical medicine is shown in the title of his Archives established in 1847. It is not surprising, therefore, that he was not satisfied with the pathology as merely the descriptive and classifying science of Rokitansky and that he was the first to recognize that pathology was the study of life under abnormal circumstances, and that chemistry, physiology and embryology had a direct bearing on pathology and that the methods of all the other natural sciences should be applied to the elucidation of the problems of pathology and thus to those of medicine.

Virchow's "cellular pathology," as announced in its final form in 1858, must be considered as a general biological principle as important in the field of its application as Darwin's "Origin of Species" published one year later.

It is said that Virchow first began the observations which culminated in his doctrine of cellular pathology in his student days, while serving as an assistant in the eye clinic of the Berlin Hospital. Here he became interested in the fact that in keratitis and wounds of the cornea healing took place without the appearance of plastic exudate. This led to an investigation which indicated the occurrence of repair by the multiplication of preexisting cells. These studies led eventually to his theory, which Lord Lister has described as the "true and fertile doctrine that every morbid structure consists of cells which have been derived from preexisting cells as a progeny." In this theory he brought pathological processes into relation with normal growth, hence his axiom "omnis cellula e cellula." This was the underlying principle, which, following Rokitansky's work in classification, gave pathology a place among the biological sciences. With his cell doctrine as a guide he made many important contributions to histology both normal and

pathological, and outlined a classification of new growths which is the basis of all present-day knowledge of tumors.

With his activities as anthropologist-archeologist we are not especially concerned except as they indicate the wide range of his interests. He was one of the founders of the German Anthropological Society, and later its president, and made expeditions with Schliemann to Troy, Egypt, Nubia and the Peloponnese.

Of vast importance to medicine, however, was his establishment of the first pathological laboratory, at the time he returned (in 1855) to Berlin from Würzburg after a political exile of eight years; an exile due to his sympathy with the revolutionary tendencies of 1848. This laboratory was the forerunner of the many which have been founded in the past fifty-five years in all parts of the world, and which have been found essential not only for the purpose of teaching and research, but also in the modern hospital. And again of importance is that influence exerted through his famous pupils such as Leyden, v. Recklinghausen, Cohnheim, Waldeyer, Kühne and Rindfleisch, to mention only the more prominent, who carried his views to other fields and continued his methods. Other great influences were to extend the territory of pathology, as, for examples, Cohnheim's conception of experimental pathology, Weigert's tinctorial methods for the differentiation of cells and tissues, Ehrlich's application of these methods to the study of the blood, Metchnikoff's studies in comparative pathology, and finally the science of bacteriology; but with Virchow remains the credit of having established pathology as a science of university rank.

The third of a century beginning in 1828 with the founding of Liebig's laboratory and ending in 1858 with the publication of Virchow's doctrine of cellular pathology, represents a greater advance in the science of medicine than the combined activities of all the preceding centuries. What was the influence of these advances on the art and practise of medicine? Medicine at the beginning of the century was still influenced by the metaphysical treatment of scientific subjects. The previous century had been one of schools and systems, those of Cullen and Brown in England, Broussais in France and Hoffman and Stahl in Germany. It was also the time of Hahnemann (1753–1844) and the rise of homeopathy. The prevailing tendency was to base disease on the study of symptoms, without regard to the underlying pathological changes causing the symptoms. A few quotations may bring this period of change from the old to the new prominently before you.

Helmholtz writes of the period of his student life:

> **My education fell within a period of the development of modern medicine when among thinking and conscientious minds there reigned perfect despair. It was not difficult to understand that the older and mostly theorizing methods of treating medical subjects had become absolutely useless. . . . We can not wonder if many honest, serious thinking men turned away in dissatisfaction from medicine, or if they from principle embraced an extreme empiricism.**

And again he says:

> At that time there were many among the younger doctors who, in despair about their science, gave up all therapeutics, and took to empiricism.

This was from a scientific man, who had much to do with the changes about to come, and perhaps somewhat biased; but we have the view of Stieglitz, an "old and learned practitioner," expressed in 1840:

> German medicine was sunk so low and is so emasculated as to require any sort of shaking up. Whatever gives it a new direction will be wholesome, though new errors or possibilities may result therefrom.

But, to continue Helmholtz's remarks:

> The right kind of work brought forth its fruits much sooner than many had hoped. The introduction of mechanical notions into the theories of circulation and respiration, a better insight into the phenomena of heat, the more minutely elaborated physiology of the nerves, speedily produced practical results of the greatest importance; the microscopical examination of parasitic tissues, the stupendous development of pathological anatomy, led irresistibly from nebulous theories to real facts.

As Helmholtz was born in 1821 his point of view is that of one who saw both the old and the new; the old in his student days, the new as one of those who labored to bring about the change. His view is largely that of the scientist, but we have fortunately the reminiscences of another, a practitioner of medicine, who labored as a student of medicine in those days of rapid change. I refer to Abraham Jacobi, our own Jacobi, "the father of pediatrics," who studied, as he tells us in his McGill address, "in three universities from 1847 to 1851, in Griefswald, Göttingen and Bonn." Referring to this period, he says:

> I have lived under the eyes of and contemporaneously with great men and during the development of modern medicine . . . not as a cooperator, it is true, but as an interested looker-on, when great things happened.

Aside from Vienna, where Rokitansky taught, there were

> only two places in all Germany in which pathological anatomy could be learned. One of them was Würzburg, there was Virchow, the other was Göttingen, there was Frerichs. So to Göttingen I went in search of pathological anatomy. . . . At the same time I looked for the advantages of chemical laboratory work under Wiggers and Wöhler.

Among the scientific happenings of Jacobi's first medical year (1847) are the following: Helmholtz's address on the conservation of energy; the use of ether anesthesia in obstetric practise by Hamner and in dentistry by Delabarre (first used by Warren at Boston in 1846); Liebig's researches on meats; the employment of prismatic glasses by Kreke and Donders; the first use of chloroform by Simpson; the employment of Duchenne of faradization in the treatment of paralysis; the discovery of unstriped muscle fibers by Kölliker and the studies by Semmelweis of the etiology of fever in puerperal women.

Among the events of the next five years, during three of which he was a student and two a political prisoner, Jacobi mentions: Bunsen's quantitative analysis of urea, the founding of spectral analysis, the use

of cold for anesthesia, Claude Bernard's puncture of the fourth ventricle and his demonstration of the glycogenic function of the liver and of the vasomotor nerves; the discovery of *Trichophyton tonsurans* and *Balantidium coli* by Malmsten, the invention of the spirometer by Hutchinson and of the ophthalmoscope by Helmholtz, and the sphygmograph by Vierordt. Altogether Jacobi tells of a host of observations made in a short period of six years. And the list is not one of laboratory discoveries only. It includes important advances in clinical medicine and surgery, as Meigs's discovery of the importance of thrombosis as a cause of death in puerperal women, Marion Sims's vesico-vaginal operation, Detmold's operation for abscesses of the cranial cavity, Walker's work on the infectious nature of secondary syphilis, Romberg's studies of tabes dorsalis, Pravaz's invention of subcutaneous injection, Kuchenmeister's discovery of the connection between tænia and the scolex found in pork, Bigelow's resection of the femur and Bennet's work on leucocythemia.

More could be quoted from Jacobi's impression of this period, but this is enough to show that medicine was advancing not only in the laboratory, but in the clinic. One may, as Jacobi says, "recognize in my fragmentary enumeration, facts of crucial import."

These advances in clinical medicine and surgery were due to several factors; to the increasing use of the methods of physics, chemistry and biology, to the influence of pathology, to the introduction of new procedures in diagnosis, and in surgery, to the facility of operation offered by anesthesia. What a change in the practise of medicine these observations and applications brought about! How different their influence from that of the earlier schools and systems with which we associate the names of Brown, Cullen, Broussais, Hoffman and Stahl!

Such schools and systems, while of interest to the general historian of medicine, offer no assistance to one seeking the lines of advance dependent on investigation or research in medicine. Fortunately for the history of clinical medicine the systematists did not occupy the field to the exclusion of those guided by objective observation, for we find Sydenham (1624–1689) and Boerhaeve (1668–1738) studying disease unbiased by schools or systems, and applying the methods of close observation which we now recognize as those of modern clinical medicine. But although Sydenham and Boerhaeve and their followers aided progress by the addition of some positive knowledge to clinical medicine, their influence on the development of medicine was not great, for they were before the days of Morgagni, Haller, Hunter, Bichat and Rokitansky and the methods associated with these names.[4] Without patho-

[4] Before and about the time of the period so represented, some of the important contributions made to clinical medicine and pathological anatomy were as follows: aneurism and diseases of the heart by Lancisi, Albertini and Senac; an investigation by Fothergill, of the diseases now known as diphtheria and tic

logical anatomy clinical classification was impossible, and without physiology and the methods of the physiologist, clinical interpretation was difficult. The influence of pathological anatomy on clinical medicine was felt first in England through Baillie (1761–1823), a pupil of Hunter; in France, after Bichat, through Louis, Andral and Lænnec; in Germany through Schönlein and Romberg; and in America through the pupils of Louis. The discovery of the diseased conditions with which we associate the names of Bright, Pott, Addison, Graves, Stokes and Hodgkins came at this time, as also Marshall Hall's discrimination of diseases of the spinal cord and Bayle's study of tuberculosis of the lung. It was the period when the best members of the profession endeavored to give to the study of symptoms the same precision as characterized anatomical observation and to combine the results of this method with the revelations of pathological anatomy. It was this method that culminated in Louis's so-called "numerical or statistical method," the method of basing conclusions on large groups of records rather than on isolated observations, and which, in this country, through the work of two of Louis's students, Gerhard and Stillé, led to the differentiation of typhoid fever from typhus fever, with which it had been confounded.

But of equal importance was the second influence which was at work, that of improved methods of diagnosis of diseases of the heart and lungs, the methods of percussion and auscultation. Percussion was first used by Auenbrugger, in 1761, but was treated with contempt and ridicule until 1808 when his pamphlet was translated into French by Corvisart, who proclaimed the value of the method and obtained for it universal recognition. Shortly after, in 1819, came Lænnec's work on the use of the stethoscope in auscultation, and Skoda in 1839 did much to extend the use of both percussion and auscultation.

This phase of medicine, the development of instruments and means of studying diseases of the internal organs and the organs of the special senses—the history of the stethoscope, the ophthalmoscope, the laryngoscope, and like instruments—is a most fascinating subject and one worthy of extended treatment, but it must suffice here to state that the new methods of direct exploration brought about a complete revolution in the knowledge of disease and had "more influence on the development of modern medicine than all the 'systems' evolved by the most brilliant intellects of the eighteenth century." (Payne.)

Exact clinical observation, the study of pathological anatomy and the increasing use of instruments and methods tending to accuracy in diagnosis were, therefore, the characteristic features of the early nineteenth century school of medicine. Both medicine and surgery were

doulourex; of prison and camp fevers by Pringle, of epidemic fevers by Huxham; of diseases of the skin by Willan, of angina pectoris by Heberden, and of gastric ulcer by Baillie.

developing along lines which ensured accelerated progress under the impetus of the discoveries in bacteriology which were soon to follow, and we could with propriety pass on to the era of bacteriology, if it were not for one great boon, destined to have an enormous influence on the practise of surgery, on the diminution of human suffering and on the general advance of research in medicine. This was the introduction of anesthesia. Surgery had steadily advanced in technic, resourcefulness and daring, but the torments of surgery were such that operations were mainly those of necessity. As Mumford says:

> Surgical pain was real enough; there was no disguising it. The terror of operation was a very hell, even in anticipation; the fact itself no man has found words to describe. The shadow of it has lengthened even to our own day. Surgeons as well as patients dreaded the knife.

Robert Liston, two years before the discovery of ether congratulated his students that the "field of operative surgery" was "happily narrowed." Keen writes:

> It is a striking commentary on the immediate results of anesthesia to learn that, in the five years before the introduction of ether, only 184 persons were willing to submit themselves to such a dreadful ordeal in the Massachusetts Hospital, an average of 37 operations per annum, or 3 per month. In the five years immediately succeeding its introduction, although the old horror could not be overcome, 487 operations, or almost 100 annually, were performed in the same hospital. During the last year (1898) in the same hospital 3,700 operations were performed.

This change was brought about in 1846, when W. T. G. Morton, an American dentist, by publicly administering ether, proved to the world that it was a safe and sure anesthetic. The operation was performed by John Collins Warren at the Massachusetts General Hospital and the names *anesthesia* and *anesthetic* were suggested by Oliver Wendell Holmes. Anesthesia was therefore essentially a Boston affair as far as its introduction to the world was concerned, but the claims of its discovery made by others (Long, Jackson, Wells, Marcy) leave the question of priority in the knowledge of and use of ether in much confusion. With this phase we are not at present concerned. One year after the demonstration in Boston, Simpson, of Edinburgh, recommended chloroform as an anesthetic of equal value with ether. Not only surgery but obstetrics, dentistry and the various specialties benefited by this great boon of anesthesia and within a year the administration of anesthetics was a universal practise throughout the civilized world. Surgery, freed of its horrors, developed along lines hitherto undreamed of, and made those rapid strides which prepared it for the era of antisepsis in the next generation.

The next lecture will concern itself with the story of Pasteur and the development of bacteriology and the influence of the latter on medicine and surgery.

AGE, DEATH AND CONJUGATION IN THE LIGHT OF WORK ON LOWER ORGANISMS[1]

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UNFORTUNATELY we are all interested in the subject of age and death. But the interest is of the kind that my friend Professor Lovejoy calls the interest of the repulsive. If we were free in the matter, we should doubtless prefer to neither hear nor know anything about the subject. But since to continue in that state of blissful ignorance and inexperience is impossible, we are driven to ask certain questions on the matter. What is the reason for our weakening and disappearing, along with all the visible living things that surround us? Why might we not as well continue indefinitely our interesting careers, instead of dropping off just as we become able to do something worth while? And *must* it be so inevitably? Is it grounded in the nature of life that all that live must die?

From the ancient seekers after the fountain of youth to the modern physiologists working toward the preservation of life, the prolongation of its processes, and the suppression of death, there have not lacked men who cherished the bold thought that death may be no essential part of life, that possibly some means may be found for counteracting the process of aging, for excluding death. And these men but express a secret wish of all mankind.

In this condition of affairs, a field of great interest was opened when the microscope revealed to us a world of organisms which seem at first view not to get old and die. As we follow them from generation to generation, the infusorian, the bacterium, seem not subject to the law of mortality. These creatures live for a time, then divide into two, and continue to live. Death appears, as we watch them, to occupy no place in their life history, save in consequence of accident.

This seemed to settle one of the great questions: whether age and death are inherent in life; inseparable from it. Here apparently was life without death; here was perpetual youth. If this can be in the infusorian, why not in other organisms, why not in man? Or if our thoughts be not so bold as this, may we not by study of the infusorian at least satisfy to a certain degree our understanding, learn perhaps something of the origin, cause and nature of age and death, and of the nature of that kind of life which avoids it? It is because I have de-

[1] A lecture before the Harvey Society of New York, March 3, 1912.

voted some years to a study of these matters in such creatures that I venture to speak to you on this subject.

You remember that one of the famous early essays of Weismann was upon the question I have just raised. He tried to show that death is not at all necessarily involved in living; that natural death originally did not exist, and does not exist now in these lower creatures; with theology he held that death was acquired in the course of time, and the Satan that "brought death into the world and all our woe" was no other than natural selection, acting for the benefit of the race, as distinguished from that of the individual. The body in the course of time becomes worn, battered, crippled. It is well to have at intervals a clearing out of this worn stock; new, fresh bodies replace the battered ones and a race which undergoes regularly this renewal must prevail and perpetuate itself in the place of those that do not; such is the conception of Weismann. Thus, too, the sum of happiness in the world is kept at the highest mark, since the fresh and perfect can enjoy much more than the worn and crippled.

But according to this view, if organisms could but live in such a way as to keep the body fresh and uninjured, there would be no need for death. And the organisms which have succeeded in doing this are the infusoria and their relatives. These, in the famous phrase of Weismann, are "potentially immortal."

But another fact in the lives of these creatures attracts strongly the attention of the observer. These same unicellular organisms that appear to live forever do likewise go through the same process of sexual union that we find in higher animals. Now this sexual union has proverbially stood as the token of mortality; it is the preparation for the new generation, and prefigures the disappearance of the old one. You will recall the famous remark of Alexander the Great upon this point.

Why then should this take place in these ever-living creatures? The fact that it does was held by many to indicate that to consider these creatures ever-living was a mistake; they predicted that these animals would be found not potentially immortal, but subject to death at the end of a certain term, just as are higher animals. It is interesting to discover here, as in so many other cases, that the diverse possible opinions on the subject were formulated and maintained before investigation had obtained evidence as to the facts in the case.

But men were not content to speculate; and Maupas in one of the great investigations of biology (1883 to 1888) undertook to determine the truth of the matter. We must look briefly at the questions which were raised, and the answers that were obtained by Maupas and by others, for it will help us to understand the present state of the matter.

Maupas took a single individual (a *Stylonychia*), kept it with plenty of food, and allowed it to multiply by repeated division into two;

he followed thus its history from generation to generation. The creatures divided every eighteen hours or so, and for about a hundred generations they remained strong and healthy. Then sickly and deformed individuals began to appear here and there; these became more and more numerous, till finally all had degenerated thus; they died out completely at the end of five months, after 215 generations. Another series, beginning with an animal that had just conjugated, degenerated and died at the end of 316 generations; and other series gave similar results.

Thus, said Maupas, it is clear that these creatures do get old and die, just as higher animals do. The idea that they are potentially immortal is a mistake; death inheres in the process of life.

But why then are not these creatures all dead? How is it that they exist at the present time?

The key to this is found, according to Maupas, and according to the suggestions of many before him, in the process of sexual union. As fertilization saves the life of the egg and permits it to continue dividing for many generations, so does conjugation put new life into the dying infusorian, permitting it also to continue multiplication for many generations. The existence of sexual union in these creatures finds its explanation in the fact that they, like ourselves, are mortal; and their mortality is overcome, like our own, by the process of sexual reproduction. Their lives begin with the strength of youth, and inevitably run down the incline of age, as do our own.

But Maupas was one of those men who are not satisfied with a brilliant hypothesis; if conjugation actually restores vitality, he wanted to see it done. He allowed one of his *Stylonichias* in the 156th generation to conjugate with another that he captured wild. Then he took one from this pair and allowed it to multiply. Most unfortunately he does not say (doubtless he did not know) whether it was the old one or the fresh one that he allowed to continue. But this creature, which had just conjugated, propagated itself for 316 generations before it finally died of old age. Meanwhile, the rest of the old stock, which had not been allowed to conjugate with fresh individuals, died out in 59 generations.

Thus it appeared to be demonstrated that conjugation restores vitality, that it rejuvenates. The brilliant hypothesis had seemingly become the demonstrated reality.

But it is interesting to the student of the history of science, and of scientific certainty, to discover that many years before the time of Maupas the function and effect of conjugation had been completely worked out in detail, by the most painstaking investigations, so that in 1862 a statement for it could be made that, according to the competent judgment of Engelmann, had been by a great abundance of observa-

tions raised above all doubt.[2] Yet this statement, though it seemed to rest on irrefragable evidence, and agreed with everything else that was known, was quite false, and in Maupas's time had been completely abandoned. Perhaps this was a type of the fate to be met by many other supposed demonstrations as to the function of conjugation, including that of Maupas—and not impossibly the one here presented.

Before leaving the work of Maupas, we must mention certain other observations that he made which are of great importance for understanding the matter. In his experiments, after degeneration had begun, many specimens within the same series (all derived from the same parent) conjugated together. But this did not rejuvenate them. On the contrary they died all the sooner after conjugating with close relatives. This happened in many cases.

So Maupas concluded (1) that conjugation with close relatives does not rejuvenate; (2) that conjugation with related individuals is not merely useless, but destructive; as soon as they do this, says Maupas, their doom is sealed; (3) that rejuvenation is due to conjugation with unrelated individuals.

This work of Maupas had of course tremendous influence; it seemed to be definitive. There appeared to be no escape from his conclusions, and for many years they were hardly seriously questioned.

But in very recent times have come a series of investigations that have shaken the conclusions of Maupas and given the entire matter a new aspect. It appears to me that the time is ripe for a revision of judgment on the whole general problem of age, death and conjugation in these lower organisms. I shall attempt to give briefly the grounds for such a revision, and the direction which the final judgment must apparently take.

1. The credit for seriously opening the question anew, as well as for getting some of the most important evidence leading to what seem to me the correct conclusions, is due to Calkins in his investigations extending from 1901 to 1904. After cultivating *Paramecium* for about 200 generations (three months) without conjugation, Calkins found that they become depressed; the division rate decreases; many die. As you remember, he found that by changing the diet at these periods, by transferring from hay infusion to beef extract, to pancreas or brain extract—the animals could be revived, and their life and propagation continued. In this way he kept them for 742 generations (23 months), but at the end of that period they finally died, in spite of any changes that were made in their food. This showed that the infusoria could be kept alive without conjugation a much longer time than Maupas had observed. Calkins kept his animals for more than twice as many generations as did Maupas.

[2] See Engelmann, *Zeitschr. f. wiss. Zool.*, II. (1862), p. 347.

The results of Calkins's experiments can evidently be interpreted in two ways:

1. It may be held that the depression was due to a too great uniformity in the food, or to the fact that the food and other conditions were not fully adapted to the animals: what the organisms needed was a change of diet. With frequent changes in diet, perhaps, there would be no degeneration at all. The final death would, on this interpretation, be due to the fact that the injury produced by uniform diet had gone too deep to be remedied by the means which Calkins tried.

2. But Calkins inclined, in view of the evidence then at his command, to another interpretation. This work came shortly after the first portions of Loeb's brilliant investigations on artificial parthenogenesis. Calkins interpreted his results in the light of those experiments. He held that the infusoria were really in senile degeneration, ready to die of old age. What he had done was essentially to induce artificial parthenogenesis; he had replaced conjugation by chemical means. The final death, he held, was due to the fact that conjugation could not be indefinitely thus replaced; old age finally asserted its power, and in the absence of conjugation produced death.

Now I think it will be apparent at this point that there are two independent questions involved in the investigations; to understand later work it is needful to distinguish them clearly.

1. Does multiplication without conjugation result in degeneration, senility and death? What is the actual cause of the degeneration that has been observed?

2. Does conjugation remedy this degeneration? An affirmative answer to this second question has been generally assumed. If animals degenerate and die without conjugation, then evidently conjugation must be what prevents and remedies this result; such has been the reasoning. But if this is true it must be possible to *observe* this effect of conjugation; we shall do well to follow the example of Maupas, and not rest till a plausible hypothesis has been transformed into an observed fact.

These two questions then suggest two lines for further work, and both of these lines have been followed.

Enriques and Woodruff have followed up the question: What is the cause of the degeneration that has been observed? I myself have pursued mainly the second question, as to the actual effects of conjugation. The results of all these investigations seem to me harmonious and to lead to definite conclusions.

Enriques, in 1903 to 1908, carried out cultural investigations which led him to the following results and conclusions:

1. If he did not take pains to keep his cultures free from the products of bacterial action, the animals degenerated in time, just as observed by Maupas and Calkins.

2. But if he did keep them free from such products, by changing the fluid every day or oftener, no degeneration took place. He thus kept *Glaucoma* for 683 generations, without a sign of degeneration, and similar results were reached with other species.

Enriques concluded that the results of Maupas and Calkins are explained by these observations. In their experiments, he holds that the continued action of bacterial products was the cause of the degeneration.

Every one with experience in such work must I believe agree with Enriques that bacterial action is a most important factor in producing degeneration and death. But it seems clear that he was in error in holding that this is the only cause. The most significant feature of his results was the fact that he kept his organisms more than twice as long as did Maupas, with no degeneration whatever. He kept them for very nearly the same number of generations as did Calkins, but in the latter's cultures there had been several crises of degeneration, which finally ended in destruction. Enriques's work indicated strongly that this degeneration was not inevitable, though he may not have explained with full adequacy why it occurs. Enriques drew the general conclusion that there is no such thing as senile degeneration in these organisms; they might enjoy perpetual youth and live without end, if only the conditions are kept healthful.

Then came the work of Woodruff, with which you are acquainted; work which appears to be definitive for the part of the problem with which it deals. Woodruff investigated the possibility that the degeneration observed by Maupas and Calkins may have been due to too great uniformity in the cultural conditions; or to the fact that the conditions employed lacked something necessary to the continued health of the animals.

He therefore carried on a set of experiments wherein certain lines were subjected to frequent changes in conditions, while others were kept uniform. As you know, this gave the key to the problem. At last accounts, the progeny of a single individual were flourishing in generations subsequent to the 2,500th, after four years and three months, without conjugation. They had been at that time kept for about four times as many generations as had Calkins's culture when it died out, yet the animals in Woodruff's experiment showed no indication of degeneration. Later work by Woodruff seems to show that if only the culture medium is properly selected, no degeneration occurs even if the conditions are kept uniform.

The work of Woodruff demonstrates that the very limited periods within which Maupas and Calkins observed degeneration has no significance for the question as to whether degeneration is an inevitable result of continued reproduction without conjugation. In other words, it annihilates all the positive evidence for such degeneration, drawn

from work on the infusoria. It justifies the statement that the evidence is in favor of the power of these organisms to live indefinitely, if they are kept under healthful conditions. It shows that Weismann was correct in what he meant by speaking of the potential immortality of these organisms.

Thus I believe that we may feel that one of our two main questions has been definitely answered. Old age and death have no necessary place in the life of these creatures, even without conjugation.

But this brings the second question back to us with greater force than ever. What then is the effect of conjugation? What rôle does it play in the life of these creatures? Are we wrong in looking upon sexual union as a token of mortality?

This is the question to which I have addressed my own investigations, and with your permission I will speak next of these.

Before taking up directly the effects of conjugation, I would like to mention two subordinate points. First, in regard to the question that we have just discussed. Five years ago I started cultures from separate single individuals. During all that time there has been no opportunity for conjugation with unrelated animals, such as Maupas held to be necessary for continued life. Yet these cultures are still alive and flourishing. Thus the progeny of a single individual may certainly continue to multiply for five years without admixture from outside. This then agrees with Woodruff's results, save that Woodruff knows that there has been no conjugation of even related individuals in the line which he follows. But Maupas found, as we saw, that conjugation among the progeny of a single individual does not help, but is actually harmful; if such individuals conjugated, their doom was sealed.

But is this result of Maupas generally true? Is inbreeding among the progeny of a single individual injurious? Or did Maupas's animals die merely because they conjugated when in a dying condition?

To test this point, I caused the progeny of a single individual to conjugate together frequently. There was no evil result whatever from this. To carry the process to an extreme, I caused nine conjugations in succession within a single line, each pair being in every case the progeny of one member of the preceding pair. Thus the forefathers of the existing race have gone through the process of conjugating together nine times. Yet the progeny are as strong and well as ever.

It seems clear therefore that conjugation with close relatives is not harmful in itself, in these creatures, though repeated many times. It is of course possible that there are differences on this point among the infusoria, just as there appear to be among higher organisms. But it is certainly not a principle of general validity that inbreeding is harmful.

But now we come to the main question. What difference does conjugation make in the life of the race?

The way to test this question is to have a set of the animals of the same parentage and history; to divide these into two groups, and to allow one group to conjugate, the other not. Then keeping the two groups under the same conditions, what difference is found to be caused by the conjugation?

In carrying out such experiments, the control set, those that have not conjugated, are fully as necessary as the other; otherwise we can not tell whether the phenomena shown by those that have conjugated are really due to the conjugation or not. Neglect to have this control set has led to erroneous conclusions in some of the work previously done.

Comparative experiments of this character I have tried many times with large numbers of individuals. As the animals begin to conjugate, they first come in contact and stick together at the anterior end, though the process can not be consummated till the more posterior regions become united. At this point then I intervened, separated the two before union was complete, and removed each to a drop of water by itself. Other pairs were allowed to complete conjugation, then the members were isolated in the same way. The two sets were then kept under the same conditions and their propagation was followed exactly. The two differ in no other respect save that one set has conjugated, while the other has not. What difference is caused by conjugation?

1. We find that the animals which were ready to conjugate, which were actually attempting to do so, are by no means in a depressed, degenerated condition, unable to multiply farther. On the contrary, if they are not allowed to conjugate, each continues to multiply with undiminished vigor. Conjugation is then not necessary for further multiplication. And we can by no means assume that because individuals are ready to conjugate, they are therefore in a degenerate or senile condition. Nor can we assume, as has been done by some authors, that if the animals continue to multiply after conjugation, this shows that conjugation has had a rejuvenating effect, for the same specimens continue equally without conjugation.

This fact, taken in connection with the results of Woodruff, explains Maupas's supposed positive evidence that conjugation produces rejuvenescence, as also the more recent results of Miss Cull.[3] In Maupas's case, which is the one that has been mainly relied upon as demonstrating rejuvenescence, after the animals had become sickly (this being due, as Woodruff's work shows, to the fact that they had lived long under conditions not fully adapted to them), he tried mating one of them with a wild specimen. He then took one from this pair, and found that it was strong and well, so that it multiplied for 316 generations. Maupas supposed that this was due to the fact that conjugation had occurred. I believe it is fairly clear that the result was not due to the

[3] Cull, Sara White, "Rejuvenescence as a Result of Conjugation," *Journ. of Exper. Zool.*, 1907, 4, 85–89.

conjugation, but to the fact that he used a wild specimen, which had not been living under unadapted conditions. He apparently used the progeny of this wild individual for the remainder of his study. Now, the results I have just described show that if he had not allowed this animal to conjugate, it would have gone on multiplying just as well. Conjugation had nothing to do with the result, the fact that the specimen came from natural conditions is what counted.

Miss Cull's evidence for rejuvenescence consisted in showing that a considerable part of those that had conjugated continued thereafter to multiply. In the absence of the control experiment, she did not discover that they continue equally if they have not conjugated. There is then in this no evidence for a rejuvenating effect of conjugation.

2. To return to my own investigations, the second important result was to show that the specimens which have been allowed to conjugate multiply much less rapidly than those which have not conjugated. The difference is very marked, and showed itself in every experiment of a great number. The multiplication is slower, in those that have conjugated, for a month or two after conjugation.

This result seems surprising, in view of the widespread impression that multiplication becomes slower and slower, when the animals are kept without conjugation, and that the function of conjugation is to raise the vitality to the pitch where multiplication may continue at the normal rate. It is therefore interesting to note that those sterling investigators, Maupas and Richard Hertwig, knew well that conjugation does not increase the rapidity of multiplication. Maupas emphasizes and insists upon this fact again and again, at much length, in opposition to the prevailing view that conjugation increases the power of multiplication. What Maupas held was that conjugation saves the animals from death, though without increasing their reproductive powers. Richard Hertwig observed, correctly, that conjugation actually decreases the rate of multiplication.

3. A third result of comparing those that have conjugated with those that have not is that many more of the former die or are abnormal than of the latter. In a specially favorable experiment, out of 61 conjugants, eleven lines had died out completely in 33 days, while of 59 lines that had not conjugated, but were otherwise similar, none had died in the same period.

4. Usually a considerable number of the conjugants never divide after conjugation, while all of those that have not conjugated continue dividing.

5. There is much greater variation among the progeny of those that have conjugated than among those that have not. This greater variation shows itself (1) in the rate of multiplication; (2) in dimensions. If we determine the coefficients of variation, we find these much greater in the progeny of those that have been allowed to conjugate.

Thus from these experiments, repeated many times, on an extensive scale, there is no evidence that conjugation causes rejuvenescence. On the contrary, it appears to be a dangerous ordeal, which sets back the rate of reproduction; and results for many individuals in abnormalities and death. What conjugation seems to do positively is to produce a great number of varying combinations, some of which die out, while others continue to exist.

Before attempting to draw more fully the conclusions from these experiments, let us follow the investigations a little farther. In conducting an investigation it is necessary not only to satisfy one's self as to the correctness of a result, but also to meet the objections of those that are firmly of the opposed view. Now, to the results thus far set forth the following objections might be made. Conjugation, it could be said, may indeed be of no use, and even disadvantageous, when organisms are in a strong, healthy condition; they would doubtless do as well without it. Probably they conjugate many times when there is no necessity for it. Yet, it might be urged, if you did not allow them to conjugate at all for many times the usual period, then possibly the need of conjugation might show itself. If you had a race that was in a depressed, degenerate condition, from whatever cause, possibly you might find that conjugation would restore them.

I therefore next carried out experiments to determine whether this objection holds. A certain race of *Paramecium* conjugates as a rule every month or two. A culture of this race was divided into two parts. One part was allowed to conjugate every month, while the other was cultivated on slides and not permitted to conjugate. In this way the one set was allowed to conjugate four times in succession, in the course of a number of months, while the other set did not conjugate at all. We have thus a set that had missed four normal conjugations.

Now, as a matter of fact, the set that had missed the conjugations did become depressed; it multiplied slowly and irregularly, and many died. This may have been due, not to lack of conjugation, but to long-continued cultivation on slides; such cultivation does, of itself, produce an unhealthy condition. But in any case, we have now a depressed race and we can test the effect of conjugation upon it. Will conjugation end the depression, rejuvenate the organisms?

The experiment is performed by putting the members of this depressed race under the conditions that induce conjugation. Then, as conjugation begins, we permit one set to complete the process, while another lot is isolated without conjugation. The two sets are then cultivated under identical conditions. We have now an opportunity to determine the effects of conjugation on a depressed race, not complicated by any other differing factors.

The results were striking, and to a certain degree unexpected. All those that had not conjugated continued to be weak and sickly, and they

died out completely in the course of several weeks. Those that had conjugated showed great variation (as usual); some died very quickly; others multiplied very slowly and finally died out; others multiplied more vigorously than any of the non-conjugants. At the end of six weeks, all those that had not conjugated were dead, while certain lines of the others had multiplied and were numerous. The difference between the two sets was in fact very striking. But it is important not to misunderstand the nature of this difference. The lot that had conjugated showed great variation, and many of the lines were not stronger than the non-conjugants, dying out fully as quickly. But a few were stronger, and these multiplied and replaced the rest. Thus after some weeks, all the survivors had come from but three or four among those that had conjugated.

But even in these the depressed condition had not been completely overcome; they were still notably less vigorous than the strain which had been kept throughout under more natural conditions and had conjugated frequently.

Thus what had happened was this: Conjugation had produced much variation; some few of the variants had been more vigorous and had lived, while the rest died.

This result when first reached was unexpected and difficult to interpret. It seems of such importance that one felt it necessary to try it again. I shall not describe to you the long and wearisome process of providing anew the necessary conditions and repeating the experiment. It will suffice to say that the experiment was repeated and gave the same results as before.

Thus I believe that we are in position to make certain positive statements as to the effect of conjugation. Conjugation does not rejuvenate in any simple, direct way. What it does is to produce variation; to produce a great number of different combinations, having different properties. Some of these are more vigorous, others less vigorous. The latter die, the former survive. This happens equally, whether the animals which conjugate are at the beginning vigorous or weak. If they are vigorous, then one of the most striking effects of conjugation is to produce some lines that are less vigorous than the original ones, so that they die out. If the animals which enter conjugation are weak, then one of the most striking effects of conjugation is to produce certain combinations that are more vigorous than the original ones, so that they survive, while those that did not conjugate die out. In a short time the entire race is replaced by the descendants of a few of those that conjugated.

Now, the relation of all this to certain things that are known in higher organisms seems fairly clear. In higher animals likewise the result of intercrossing is to produce variation. We don't call it variation nowadays, because we know something more about it; we call it

Mendelian inheritance. In the crossing of two individuals that resemble each other externally, progeny of many different kinds are produced. In crossing white and cream-colored four o'clocks Correns got eleven kinds of red, white, yellow and striped offspring among the grandchildren. Heredity, as the Mendelian analysis has revealed it to us, is a process of producing a great number of diverse combinations by the varied intermingling of the characteristics (concealed or apparent) of two individuals.

Now, it seems clear that this is exactly what is done in the conjugation of the infusoria. We have not yet succeeded in determining the precise rules of recombination, such as have been worked out for many cases in higher organisms; so that for the infusorian we are as yet limited to the statement that conjugation produces variation.

Thus the conjugants apparently have the same relation to each other, so far as inheritance is concerned, as do sperm and egg in the higher organisms. We ought to find that the progeny inherit from both of the conjugants. What are the positively known facts as to this?

Regarding biparental inheritance in these lower animals, we are as yet in that relatively backward stage of science that is implied by the necessity for the use of statistical methods.

We hear at times the Kantian dictum that any subject is scientific only to the extent that it makes use of mathematics. This dictum is sometimes put before us as an argument for using statistical methods. But for these we could almost reverse the statement, and say that any subject is scientific only to the extent that it can dispense with statistical methods. These are necessary mainly when we can not understand and control the separate causes that are at work; as soon as we can do this such methods become largely unnecessary.

But the use of statistical methods enables us to show that in conjugation the progeny inherit from both parents. By working out for the rate of fission the coefficient of correlation between the descendants of the two that have conjugated, we find that they have nearly the same closeness of relationship as brothers and sisters; and somewhat closer than cousins. The coefficient of correlation is about .4. This means that if the progeny of one member of a pair have a peculiarity, the progeny of the other member have the same peculiarity, though in a less degree, and this similarity can apparently come only through inheritance from both parents.

Comparing conjugation with the fertilization of higher animals, we find then this state of the case. In higher animals fertilization has two diverse effects, which recent investigation, particularly that of Loeb and his associates, has clearly disentangled. (1) On the one hand, it initiates development; it prevents the egg from dying, as it would do if not fertilized. This function of fertilization is the one that is replaced by the processes which induce artificial parthenogenesis.

(2) But, secondly, fertilization brings about in some way inheritance from two parents. When there is inheritance from but one parent, the inheritance is as it were complete; the child as a rule resembles its parent in all hereditary characteristics; this is the result of the so-called "pure line" work. But when we have biparental inheritance, a great number of different combinations of the characteristics of the two parents are produced, so that the process of fertilization is one that in this respect completely alters the face of organic nature, producing infinite variety in place of relative uniformity.

These two functions of fertilization, the initiation of development, on the one hand, the production of inheritance from two parents, on the other, are logically independent; they might conceivably be performed at different times and by different mechanisms. The fact that in many organisms the same mechanism that brings about biparental inheritance is likewise the one that initiates development might from certain points of view be called an adaptation. Its result is to insure that in *all* the organisms that develop there shall be inheritance from two parents, not from one. In the work on artificial parthenogenesis these two functions have been separated experimentally; the initiation of development takes place alone.

Now, in endeavoring to understand conjugation, attention has been given hitherto almost exclusively to the first of these two functions. It was held that the function of conjugation must be to make possible life and development where it was otherwise impossible, just as fertilization arouses the egg to further life and development. But it turns out that conjugation, instead of having this one of the two functions of fertilization, has the other. The two functions are in the infusorian separated, just as they are in artificial parthenogenesis, but it is the second, not the first, that we have before us. Conjugation is not necessary in order that life and reproduction shall continue; they continue without it.

But the life which thus continues is uniform and unchanging. To give biparental inheritance, with varying mixtures of the characteristics of the two parents; to produce these new combinations in great variety, conjugation is necessary. And when this happens under such conditions that the original combinations were not adapted to survival, then some of the new combinations produced often are adapted to the conditions; conjugation then results in a survival of an organism that would have been completely destroyed without it. It is most interesting in this connection to observe that conjugation is usually induced by an unfavorable change of conditions, a change of such a nature that the organisms begin to decline. Thereupon conjugation occurs, so that new combinations are produced, adapted to varied conditions, some of which may survive.

Thus it appears to me that the whole series of investigations on old

age and on conjugation leads to a unified result, and one that is in most respects in consonance with what we observe in higher animals. But in one respect there is a difference, and this brings us back to the question with which we began. Is death a necessary accompaniment of life? Do the life processes necessarily take such a course that they must lead to death?

To this question the work on the infusoria answers *No!* The evidence that was supposed to show that the life processes must gradually run down and end in death had been shown by the work of Woodruff not to lead to any such conclusion. Woodruff appears to be clearly justified in his recent statement that these organisms "have the potentiality to perpetuate themselves indefinitely by division," and my own studies on the effects of conjugation furnish the complement to this result, agreeing with it fundamentally.

All that Weismann meant by saying that such creatures are potentially immortal has shown itself correct. Death is not necessarily involved in life.

But why, then, in higher animals and in ourselves, even when there is no accident and conditions are good, do we find death coming as a natural end to life? Why should there be this tremendous difference in such an essential point between the lower organisms and the higher ones? Is there any possibility of mistake as to the necessity in the case of higher organisms?

To find a ground for this difference, we shall do well to follow the usual procedure in science, and examine other differences between these lower creatures and the higher ones, to see if these may not give us the clue. And here I touch upon a matter that had been fully developed by Minot and others; it is worth while to speak of it briefly, because work bearing upon the matter has recently appeared.

The most striking other difference between these lower organisms and the higher ones, is evidently the fact that in the higher organisms the body becomes large, complex and differentiated into a number of diverse parts; different cells of the body have taken on themselves different functions and different structures. This appears to involve a correlative loss of the power of carrying on the fundamental vital processes; the cell that has become filled with lime, or that has transformed into muscle, no longer retains the vital elasticity of the cell in which the diverse functions remain well balanced. Products of metabolism are no longer perfectly removed; other processes necessary to life become clogged. The final result of this is a complete cessation of the processes; age and death follow upon differentiation. This, as you know, is the theory of Minot. According to it, the welfare of the individual cell is as it were sacrificed to that of the body as a whole, and this in turn involves the final destruction of the body itself, so that a

period of higher diversified life is purchased at the price of ultimate death.

Minot has added to this fundamental idea certain views as to quantitative relations of nuclear and cytoplasmic material in the cell. Relative increase of cytoplasm is taken to be the beginning of the process of aging, while relative increase in nuclear material is considered a process of rejuvenation. Such rejuvenation was held therefore to occur in the early cleavage of the egg, since here the amount of nuclear material was supposed to increase greatly in proportion to the amount of cytoplasm.

The recent important paper of Conklin has shown that in the cleavage of many animals this increase of nuclear material relative to the cytoplasm does not occur. Conklin's results will apparently go far in rendering untenable or modifying all theories in which great significance is attached to the precise quantitative relations between nucleus and cytoplasm. But what is important to realize is that this has no bearing on the fundamental feature of the theory that aging and death are due to differentiation. The grafting of the theory that the quantitative relation between nuclear and cytoplasmic material is an essential point upon this general theory was unfortunate from the beginning.

Everything points, it appears to me, to the essential correctness of the view which holds age and death to be the result of the greatly increased differentiation of larger organisms. Is there then any probability that we shall some time find that in the higher animals, as in the lower ones, death need not occur?

Evidently not. If death is the price of differentiation, then after the goods have been delivered the price must be paid. To prevent a higher organism from undergoing death would at the same time prevent him from becoming a higher organism. And the cell which remains in the embryonic condition—the cell of the germ glands—is even now as immortal as the cell of the infusorian. Death, as Minot says, is the price we pay for our more complex life. Age and death, though not inherent in life itself, are inherent in the differentiation which makes life worth living.

CONSERVATION IDEALS IN THE IMPROVEMENT OF PLANTS

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THE conservation movement had its inception in the wasteful methods practised in the utilization of our national resources, such as our forests and mineral deposits. Alfred Russel Wallace, the great English evolutionist and contemporary of Darwin, has characterized the last century as a century of despoliation of the natural resources of the earth. Our forests have been ruthlessly destroyed until good lumber has reached a very high price, and turpentine and resin in sufficient quantities to meet the world's requirements can scarcely be obtained. In the meantime large areas, denuded of forests, have been changed in climatic conditions and the fertile soils exposed to destructive erosion. Coal beds are being worked in ever increasing quantities and must ultimately be exhausted. The Chilean nitrate-of-soda deposits are approaching exhaustion. We use without thought of the morrow. The conservation movement has extended to the consideration of soil fertility, the proper utilization of water, of water power, of our land domain, and the like.

There is scarcely any source of wealth or of material necessities that has not felt the influence of the conservation movement. If we seek the real source or reason for this inquiry, it is to be found in the rapid increase of our population. The arguments are too familiar to require repetition. We all know that the population of this country and of the world is increasing so rapidly that the time is not far distant when our children will have great difficulty in producing the necessary supplies to maintain life. The teeming millions of fifty and one hundred years hence will not have the rich, virgin lands on which to extend their agriculture, the primeval forests, the apparently inexhaustible coal beds, the extensive deposits of phosphates, nitrates and potash salts, to use in rebuilding their soils. All these sources of supply that we have utilized and found so necessary to life will be gone or rapidly disappearing, and the extent of the demand will meanwhile have increased many fold. It takes no very extraordinary vision to picture the fierceness of the struggle for existence that must soon be reached in the development of the human race. True, there is no immediate concern, as the world will comfortably support a very much larger population; but to preserve future generations from danger requires the wise action of the present and succeeding generations. The careful study of the

problem in all its phases is a duty that we can not shirk. The high cost of living at the present time and the simpler living that thousands of families have been compelled to adopt is a reminder of the necessity, even to the present generation, of a careful study of the existing conditions.

The problem of all problems confronting us is the necessity of increasing the production of food stuffs. How can this be done? Obviously the problem can be attacked from many sides, but the side that I desire to emphasize is the conservation of the best breeding stock of plants and animals. This seems a simple matter, but I am sure that the far-reaching possibilities of such conservation are not understood and are beyond our conception at the present time, as our viewpoint is necessarily limited by our present knowledge. Nevertheless, as judged by our present knowledge, the possibilities are so great as to place this factor, I believe, among the important features of the conservation movement.

What do we not owe to our domesticated and improved plants and animals? They are the greatest heritage that has come down to us from our ancestors. If the cultivated varieties and breeds of wheat, oats, corn, cotton, potatoes, cattle, sheep, hogs and horses were all destroyed from the earth and we were forced to go back to wild nature and begin the improvement over again, it is probable that the world would be almost depopulated and that the progeny of the few hardy individuals that survived would, in the centuries that followed, repeat the history of plant and animal improvement that has taken place in the past. Doubtless, however, new plants and animals now unknown to us would be the successful ones in the new evolution. That we now cultivate wheat, oats, corn and the like is probably in large measure due to the accident that attempts to artificially cultivate plants started in regions where the wild ancestors of these plants were native.

In many cases the wild ancestors of our cultivated plants are not positively known. It is not probable that the ancestral types have become extinct, but that the cultivated forms have been so greatly modified that the relationship can not now be recognized with certainty. If *Ægilops ovata,* a wild grass of southern Europe, is the original ancestral form of wheat, as is supposed by some botanists, we have very many native grasses in various parts of the United States, which in an unimproved state have much larger grains and would seem to be equally worthy of cultivation and improvement. If Teosinte (*Euclæna luxurians*), a wild native grass of Mexico, is the original wild ancestor of corn, as is believed by many scientists because of the fact that it is a native of the region where corn was first cultivated, is known to be subject to the same diseases, such as smut, and above all from the fact that it hybridizes readily with corn, we have an unpromising grass, so far as its

grain is concerned, which has developed into our greatest of all grain crops.

Are we correct in assuming that all of the valuable plants and animals have already been introduced into cultivation? As a matter of fact, are we not justified in questioning whether the most valuable have been introduced? On sober second thought, does it not seem wonderful that wheat, a native of the Mediterranean region, should remain the best grain crop for a region including the greater part of British America and the United States, of Russia and Argentina and all the broad area where wheat is cultivated? Would it not seem probable that the improvement of the most promising native grain-grasses in these widely different regions would yield new types of grain crops better adapted to the regions and superior to wheat or oats? The great value of wheat and oats lies not in the superiority of the wild types from which they sprang, but to the long years of cultivation and selection to which they have been subjected. A large number of wild grasses occurring in almost every region have comparatively large grains, and if they were capable of improvement, as they doubtless are, they might possibly excel any grains that we now have. The Indian rice or water oat (*Zizania aquatica*) is an illustration of a large-grained wild grass that is probably known to many. Doubtless this could be greatly improved for cultivation in low lands as rice is now cultivated.

The wild wheat grass (*Agropyrum occidentale*) of the great plains region is a very promising type for improvement, as pointed out by Dr. Bessey.[2] In this wild grass we have a head 5 or 6 inches long and developing long, narrow grains much resembling wheat. It is a perennial and grows to a height of 2 or 3 feet. Dr. Bessey says of this plant:

> If our plant had had but a fraction of the careful cultivation and selection which have been given the European species, I am confident that it would have yielded a much more productive cereal than we have in our present varieties of wheat.

Consider further that we have here a perennial that would doubtless yield for several or possibly many years without reseeding, and also that it is a native of the great plains region and thus already adapted to the environment of the great wheat states of the union. Comparing this grass with wheat, which should we expect to be better adapted to the "dry farming" regions of the west?

Several of the wild rye grasses (*Elymus*) have large heads and grains and appear very promising, as do also certain species of the so-called beard-grass (*Andropogon*).

We have only considered the value of these grasses from the standpoint of their grain development; but it is of almost equal importance

[2] Bessey, C. E., "Crop Improvement by Utilizing Wild Species," American Breeders' Association, Vol. II., p. 113.

to consider their value as forage crops for animal food, and here a much greater latitude for selection is possible. A very large number of our native plants should be tested and the most promising improved for forage purposes.

In the development of leguminous crops we have a valuable field of research. Of the many hundreds of legumes, we now cultivate only about a dozen species, such as beans, peas, clover, alfalfa, crimson clover, cowpeas, soy beans and the like, representing a natural adaptation to as many localities. None of the species ordinarily cultivated in the northern United States are natives of this great section. Yet an examination of the botanies shows that some 150 different species of legumes are natives of this section. Would it not seem absurd to assume that our present cultivated species represent the best types for this section, when the most promising of those that the great Master Breeder gave us have not been thoroughly improved and tested? Among the wild native species of *Desmodium, Vicia, Lespedeza* and other legumes, we have a number of promising sorts. We have tested many of these species in comparison with our ordinary cultivated crops and discarded them, but our tests have been of the wild, unimproved, against the improved types. We might as reasonably put gloves on a wild pygmy of Africa and test him on the mat with a trained modern athlete.

Doubtless the mere mentioning of the improvement of native plants suggests to the minds of each one of you some wild plant that you have observed and thought to possess valuable qualities. If our sources of nitrogen supply are to be exhausted soon, we must cultivate more leguminous crops that can gather their own nitrogen and improve the soil in this respect while furnishing crops. We should have leguminous tuber crops to take the place of potatoes, beets and turnips. Nature has given us such wild legumes as the groundnut (*Apios tuberosa*) and the Pomme de Prairie (*Psoralea esculenta*), which already have edible tubers and which could doubtless be developed into very valuable cultivated plants by a few years of breeding.

Dr. J. Russell Smith,[3] of the University of Pennsylvania, has emphasized the importance of breeding tree crops, and here we have an inexhaustible field of experimentation. We should breed chestnuts, walnuts, hickories, oaks, beeches, hazelnuts, and the like, in order to improve them for the use of man and for growth as stock food. Many hundreds of thousands of acres of rough, hilly land unadapted for cultivation would be suited for the growth of such crops.

The possibilities of breeding tree crops are well illustrated by the excessive increase in vigor, rapidity of growth and size of fruit obtained by Burbank in a hybrid between the English walnut (*Juglans*

[3] Smith, J. Russell, "The Breeding and Use of Tree Crops," American Breeders' Association, Vol. I., p. 86.

regia) and the California black walnut (*J. californica*). Burbank says:

> The hybrid grows twice as fast as the combined growth of both parents. The leaves are from 2 feet to a full yard in length. The wood is compact, with lustrous, silky grain, taking a beautiful polish, and as the annual layers of growth are an inch or more in thickness and the medullary rays prominent, the effect is unique.

Another of Burbank's walnut hybrids obtained by crossing the black walnut with pollen of the Californian black walnut, produces fruit of very much larger size than either parent. When we come to plant large areas to trees, as we are rapidly coming to do, imagine the immense value to the world if we could plant hybrids of rapid growth such as Burbank's walnuts.

Who has tried to produce hybrids of maples, oaks, hickories and pines to get quick-growing hybrids for planting purposes? Who has hybridized such trees to get larger and better fruits? The world should not be compelled to wait much longer for such improvements. We need the improved stock for planting. Some trees live a century before they reach young manhood.

Persimmons, pawpaws, huckleberries, elderberries, hawthorns and hosts of other native fruits are well worth improvement and might be utilized not only for human food but for hogs, sheep and poultry.

Mr. Frank Babak, of the Department of Agriculture, has recently shown that the black sage (*Ramona stachoides*), a wild California plant, and the swamp bay tree (*Persea pubescens*) of the southeastern United States, both contain a fairly high percentage of camphor and could be utilized for the manufacture of this valuable product. Doubtless these plants could, by breeding, be adapted to cultivation and the percentage of camphor increased.

The value of improving native plants has been strikingly demonstrated by the amelioration of our native grapes. The attempts of our early ancestors in America to grow European grapes uniformly met with failure, and finally, as a last resort, attempts were made to cultivate the native wild types. The marvelous success achieved, which has resulted in the production of a large number of fine varieties, and established vine growing in the eastern and central United States, is one of the important achievements of our many-sided national history.

The same was true in the case of the gooseberry. The European varieties failing to succeed here because of the mildew, the small fruited native species were introduced into cultivation, and the size of the fruits has been more than quadrupled in the improved sorts. Plums, raspberries, blackberries and the like furnish other illustrations of interest.

The native wild beggar weed (*Desmodium tortuosum*) has been introduced into cultivation in Florida, and, without breeding or im-

provement of any kind, has in a few years won a permanent place in southern agriculture.

It may be argued that the improvement of our native plants would be too slow to justify attempts in this direction. I should answer that nothing is too slow that will pay. Nations bond themselves for hundreds of millions of dollars to carry on a war of the present, which bonds their children must pay sometime in the future, and for no compensation except to maintain the pledged honor of the nation. While breeding is slow when judged from the "get-rich-quick" standpoint of modern Chicago, it is not slow when compared with the life of a nation and from the standpoint of permanent welfare. Within the memory of man the tomato has been introduced into cultivation and advanced in size from a fruit of $\frac{3}{4}$ of an inch in diameter to our fine modern fruits, some of which grow as large as 4 inches in diameter.

A striking illustration of this nature is furnished by the experiments that the writer has conducted in the improvement of timothy. Timothy was introduced into cultivation about 1720, nearly two centuries ago. For many years it has been extensively grown, but, until recently, no attempts have been made to develop improved races. In experiments conducted by the Cornell Experiment Station, timothy seed was obtained from a large number of places in this and foreign countries, from which about 18,000 individual plants were grown and the different types studied and isolated. As a result of 9 years of work, some 200 different races have been secured that show a very wide range of characters, and vary from dwarfs to giants in size. A test of the yields of 17 of these new varieties in comparison with the best timothy seed that could be purchased in the market was made in 1910, and also in 1911. In 1910 the average yield of the 17 new sorts was 7,451 pounds per acre and that of the 7 check plats of ordinary timothy was 6,600 pounds per acre; an average increase of 851 pounds per acre in favor of the new varieties. In 1911 the average yield of the 17 new sorts was 7,153 pounds per acre and that of the 7 check plats was 4,091 pounds per acre; an average increase of 3,062 pounds per acre in favor of the new varieties. Four of the high yielding sorts in 1911 gave an increased yield of over 2 tons per acre, or practically double the average yield of the checks, which is an astonishing figure and can be explained only by the fact that timothy has never been improved by breeding and still consists, as generally cultivated, of a motley array of many different types.

Hay is one of the largest agricultural crops of the United States, outranking all other crops, except corn, in total value of production. In 1910, according to the statements issued by the United States Department of Agriculture, there were grown in the United States 45,691,000 acres of hay, which yielded a crop having a farm valuation of $747,769,000. No statistics are available from which we can determine

what proportion of this hay was timothy, but the writer believes that we may safely conclude that at least one third of the entire hay crop of the country is timothy. If this is true, the timothy crop of the United States in 1910 had a valuation of over $249,000,000. In the two years during which tests have been made, the 17 new sorts gave an average increased yield of slightly over 36⅔ per cent. above ordinary timothy. A 36⅔ per cent. increase in the valuation of the timothy crop as above estimated would give us over $90,000,000 as the estimated annual gain in the value of the crop which would be obtained if new sorts equally as good as these could be used throughout the country.

The rapid development of the science and art of breeding places us to-day in position to secure improvements much more rapidly than has been done in the past. It would not be astonishing if from 25 to 50 years of careful, intelligent breeding would accomplish with a wild plant what has required many centuries under the crude methods of our ancestors.

It may be asked why we should be in haste to take up the improvement of our native plants. In answer to this it may be stated that profound changes, such as we desire and must have, require time for their accomplishment. The potato and the tomato did not reach their present perfection at one bound. A number of intermediate stages or improvements were first necessary. The strawberry and the gooseberry did not reach their present size by one mutation, but several intermediate sizes were first necessary. Improvements apparently come by sudden leaps or mutations, and each of these paves the way for further development that might never be possible without the first improvement.

In breeding, the time element is the limiting factor of importance. No permanent improvement of value can be obtained in a day, and no time should be lost in beginning, on a scale commensurate with its importance, the improvement of our native plants of promise. We must conserve time and fulfill our duty to the succeeding generations. Why is it that such a small proportion of our lands are cultivated? According to the 1900 census, of the 1,900,000,000 acres of land in continental United States only 838 millions of acres were in farms, and of this area over 50.6 per cent. was unimproved land. The sterile sandy lands, and the low, wet lands, the stony lands and the hill lands, the mountain lands of high altitude and the barren lands of deserts lacking water, and the like, all uncultivatable and largely worthless for crops at present grown, make up far the larger part of our vast domain.

Travel through the high, hilly and mountainous regions of New York, Pennsylvania, Maryland, Virginia, North and South Carolina and Georgia, and you find vast areas covered mainly with a low growth of young trees and bushes, the main forests having been removed. The same is true of many extended areas in the central and western states.

The utilization of these waste lands forms one of our great national problems, and the beginning of the solution of the problem rests in finding the crops best adapted to such areas or in all probability in breeding crops that will be adapted to them. The necessity of using these waste lands in the near future is evident. Shall we plant them to forest? Certainly much of this land should be in forest, or in tree crops of some sort, but we want tree crops, at least in many cases, that will return food as well as shelter. The Italian yield of chestnuts is said to average 12 bushels per acre, and J. Russell Smith states that "the value of European mountain-side chestnut orchards equals acre for acre the Illinois corn belt." The kinds of trees to plant in such areas for wood, fruit, sugar, starch, camphor or forage require careful study and the proper breeding in order to secure the best sorts possible.

But this is not all of the problem. Grain, forage and special fruit crops, not necessarily forest trees, require to be as carefully considered, and here again breeding to secure good races adapted to the conditions will be the key note of success. All this requires time, and the generations to follow will not have the time and certainly not the money if they do not repudiate our war debts. The work should be started immediately in order to obtain the results by the time conditions demand them. When I urge this as one of the important national problems of conservation, I speak not without some authority. My life has been given to agricultural work in various parts of the United States. My boyhood on an Iowa farm gave me a knowledge of the rich prairie regions of the west. My education in the University of Nebraska and Washington University, Missouri, extended that knowledge. My sixteen years of service in the National Department of Agriculture, working with cotton and oranges in Florida, Georgia, Alabama, Mississippi and Texas, taught me southern conditions and demands, and now my experience of the last five years in Cornell University, associated with that master agriculturist, Dean L. H. Bailey, has broadened my horizon to at least some conception of the field of agricultural education.

As to the possibilities of producing the suggested improvements in plants, it again may be granted that I can speak with some degree of authority in view of the fact that the great cotton, corn, timothy, orange and pineapple industries have, at least in certain places, felt the influence of new varieties that have gone out from my laboratory. I say this not to extol myself, as any man in my place with my opportunity could have accomplished the same results and many would have done very much more. I say it simply to lend weight to my statements.

I can by no words of mine present this problem in its importance as I see it. In no way, probably, can my efforts stir the nation to a recognition of the necessities of this case, so that action will not be too long delayed. Recognizing the urgency of the problem as I do, how-

ever, I should be remiss of my duty did I not use such powers and gifts as have been given me to urge forward a project that sooner or later will be recognized as one of the keystones of the conservation movement.

The materials for the consummation of the ideals I have presented are all around us. The brawn and brain for the service is awaiting the opportunity. The service will be long and difficult, however, and the servant must live while engaged in the task. Only by long, consecutive years of service can the highest ideals be reached. Men must consecrate their lives to this achievement. The service will be pleasant and the scientific results gathered from year to year will repay the worker, but means must be found to place the investigator beyond the temptation of other employment, as permanency of tenure in such work will be of the highest importance. It is a work for the state and the nation, but I fear they will be too slow to recognize the long-time requirements of the work. Political institutions demand too quick results. I feel that the most hopeful method of accomplishing some of the ideals outlined is through endowed institutions. To what more serviceable task could benefactions be devoted than to the solution of such problems, and what type of institution would return more credit to the donor? Institutions to conduct such work could be tied up with some of our great universities to establish the proper scientific relationship, and should be in such close cooperation with these universities that graduate students could be utilized in connection with the investigations and trained in the service.

In summarizing this discussion I may say that to one unfamiliar with the possibilities of breeding the outcome of such experiments may appear doubtful. We need no lamp to guide us except that of experience. When we realize the little promise exhibited by the native grapes, tomatoes and potatoes from which our cultivated sorts have sprung, we gain a conception of the tremendous increases that can be brought about by a century of cultivation, even when the breeding is of desultory nature. Couple with a century of time, aye fifty years, the skill of trained breeders, and what might we not accomplish. The greatness of the possibilities stretches before the enthusiastic breeder as his mind spans the years filled with the battles of conquest and achievement in the building up of new industries, like a panorama of the wars and struggles in the building of a nation. Man's creative genius is touched. It appeals to him in its vastness as a challenge. The trained man in the field of breeding feels the certainty of his power. He longs for the conquest.

A PHILOSOPHY OF GEOGRAPHY

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IN the minds of many persons to-day it might seem necessary to apologize for holding to a "philosophy of geography," that study often remembered from school days with either utter dislike or disinterest; for in early years it was a bugbear to carry about the "big geography" in between the covers of which were gathered the colored maps of the various countries, with descriptions of those countries and their boundaries, products, exports, imports, rivers—a real Baedeker of the earth. Even later most of us were hurried along, not given time to catch our breath or have our wonders satisfied; and to-day, perhaps, there are still some who wonder at the college professor's giving serious thought to a subject of which they learned all there was to be learned during the years of schooling.

But such remembrances are probably becoming fewer, for in the minds of many thinkers to-day there is no doubt that the science of geography is one which furnishes much food for thought and much opportunity for research. Not only in the works of many of the older thinkers and philosophers, but also in the pages of various current periodicals and in some of the excellent modern histories, may one see something of the attitude which endeavors to view many human activities in their relation to the geographic stage. From making the study of geography dwindle into a mere recital of fact—with what hours of dullness or dryness!—it may be of interest or profit to somewhat fully give to geography a place beyond that of a mere catalogue of distribution, and to enrich its apparent field by glancing at some of its interesting causes and tremendous effects.

As was suggested, the mental image called forth by the word geography would doubtless be to many a mass of disconnected details, dealing chiefly with the idea of localization and definition and the remembrance of things in themselves uninteresting. An island was a mass of land entirely surrounded by water. An isthmus was a neck connecting two large areas of land. Why the island existed, or how it came about were "hideous secrets." Why two bodies were connected by a constriction may have been a mystery, and one was never led to solve it. "What was the capital of Missouri?" "For what product was Iowa famous?" "What crop comes from the northern plains?" "Name ten large cities of America." No one thought of enlightening the, perhaps,

curious minds as to why the ten largest cities were largest. They merely were. No one tried to tell why the great wheat plains were plains. They just were. Yea, verily have many been piloted about the earth, passing with kaleidoscopic haste picture after picture, cramming their heads with encyclopedic facts until they were made aching by the rush of detail. Truly were they as the summer tourist with red Baedeker in hand, seeing and learning.

Geography is not a mere placing of things upon an earth. It is not a subject fit only to be placed in childhood's curriculum and passed through hurriedly during immature years. Geography ought to awaken an interest and kindle an enthusiasm rivaled by few other sciences, to all minds, the mature as well as the young, because of its far-reaching relations. What about the romance of the forces of the earth, the beauty of topographic expression? Why not see in the tiny trickle of the rain gully the roaring, destruction-bearing Colorado? or behold in the frozen cap of the pond ice the wasted expanse of Greenland's glaciers?—or picture in the muddy sidewalk the tons of débris dumped by the Father of Waters at New Orleans to add new lands to the old?

Vermont may be a great producer of slate. But why? What a story a piece of Vermont slate might tell!—of a time many thousands of years ago when beneath the sea were being deposited muds worn from the land beyond. Then, deeply buried beneath overlying sediments, the clay became pressed to a firm shale. In the turning and folding of the whole mass to make new land, the heat of the disturbance baked the shale, and the pressure of the overlying rocks developed in it the fine planes of cleavage; the shale became a slate. And the wearing of the rocks above by the processes of erosion brought to man's view the roofing of his home! Then, too, compare the passionate temperamental Italian with his more stable and phlegmatic cousins of the north. Is it just "the nature of the beast"? or is there a "why"? Why is the oriental art so rich in all its riot of color? Why the prominence of Philadelphia, Chicago, Richmond? Why the steel rails of Pittsburgh?—the great fruit produce of New York?

These and many like questions may give an insight into the "different" way of thinking of geography. For, although all of us will admit that what we have or are is because we are of the earth's food, shelter or clothing—the three R's of life—yet I want to suggest some of the perhaps less well known but just as interesting correlations between ourselves and geographical conditions.

The earth supplies man with the necessities of food, clothing and shelter, which, naturally, differ in different parts of the world. And yet in each locality man has adapted himself to these differences. The

relationship of man to the physical things of the earth is one which can be traced out in the minutest detail, especially, of course, in primitive communities where food is absolutely dependent upon geographic location. The Esquimaux, with no forest or sandy deserts, eat of fish and game. The fruits supply the tropical savage, there where the warm climate supports a variety of vegetable life, so that the native has but to step from his grass hut to find his daily bread. Pastoral peoples have their milk foods, dwelling as they do in the sweeping plains of Australia or Russia which support flocks of sheep and herds of oxen. Moreover wheat, corn, maize, meat, which are all products of the physical earth, of climatic and geographical conditions, go far to shape the man of the temperate zone.

Likewise, compare the leather garments of the shepherd, the fur coat of the Lap, the woolen garment of the Russian, the grass dress of the Australian, and see in them the influence of geography. Or, trace in the adobe hut of the plainsman, the sod homes of the tropical savage, the inglow of the Esquimau, and the skin tents of the nomads, in the carved stone buildings of the cave dweller, in the log hut of the forester, in the cobble house of New York state, a like influence of geography upon the sheltering places of man.

As for occupations, does not one see in the hunting of the African wilderness, the herding on the plains of Patagonia, the agriculture of the river valleys, the mining of the mountains, the lumbering of Canada, the fruit growing of California a relationship with the geographic field? When a community possesses more material than can be utilized by it, peoples begin a trade, thus establishing commercial relations, with the development, on a large scale, of agriculture, manufacturing and other industries. Man would not have made rugs in India, for there was no wool. Nor would he have made gold ornaments in England, for there the gold was absent. The Persians made rugs, for wool was at their door; the Hindoos carved gems, for Indian plateaus were pregnant with them; the Chinese wove costly silks, for in their country the silk worm flourished; the Norsemen built boats, for in their country lumber was cheap. In short, in many places, as raw materials were present, so manufactures grew—porcelain in Japan, rugs in Persia, ships in Norway, pottery in England, steel in Birmingham, smelting at Denver, cement in New Jersey. Power is needed in extensive manufacture, and where power is cheap or easily obtainable there may arise immense industrial centers, as at Birmingham, Pittsburgh and Niagara Falls—where fuel is at a stone's throw away, or where the mighty rush of water furnishes energy, and where it is often comparatively cheap to bring, for manufacture, raw materials produced elsewhere. Often, too, where places are favorably situated along travel lines of least resistance there may grow up populous centers as Buffalo, Saint Louis, London and New York.

Let us now view a few more historical facts in this limelight of geography. The history of geography, which leads to the geography of to-day, is a record of achievement, colonization, trading, conquest, religious zeal, and scientific endeavor. The nomads move because the environment will not support them. Disturb an environment and see the result. Block the trade route from Europe to Cathay as did the Turks and a new world is discovered. Block this route and Venice trade passes into the hands of Portugal. Pierce the Isthmus, and Japan is at your doors. As Keltie has so well pointed out, the first great civilizations, Babylonian, Egyptian, Chinese and Indian, began in the great river valleys. They were non-cosmopolitan and isolated civilizations, for they were content in the fertile valleys of the Nile, Euphrates, Ganges and Yang-tse-Kiang. Contrast with theirs the spirit of the Phœnicians, the sturdy and fearless seamen of the pre-christian era, forced to trade by the non-fertile condition of their strip of country. See the physical development of the Greek, his intellectual stimulus inspired greatly by the multitude of topographic conditions. How did the Himalayas affect history?—serving as a barrier, hindering the migration of both man and beast, and protecting the people from invasion? Among mountain people many ancient customs are preserved. Because the Scotch and Welsh were much less affected by invasion than other parts of the British Isles during time of inroads, some of the oldest of their dialects still linger with them. The *Basques,* a small body of people in the Pyrenees, still speak a language spoken by no other race. Why has Switzerland been able to remain independent? Because the brisk air of mountains helps to develop a brave, hardy people, and because of her impregnable position among the Alps. Why did the early American settlers locate along the Atlantic coast and not push towards the west? The Appalacians served as a barrier to the spread of the early colonists and sheltered them from the savages of the west. Why was Alaska exploited? The gold in her gravels. England owes much of her historical importance to the geographical fact that the sinkings of the land give the coast such an irregularity of outline as is always favorable to the development of navigation, commerce, fishing. Why has Austria been from time to time the scene of inroads by Asian peoples? Because she lies open to the Black Sea and the plains of central Europe.

Man, with certain limits, differs from his lower cousins of the animal family by being able to take his environment by the forelock and make use of it for his own convenience. He constructs a Suez canal, he removes a mountain from his path by carving a Simplon tunnel, he brings fertility to arid New Mexico; he drains Arkansas swamps, he rescues Holland from the sea, he changes the course of the Mississippi. Indeed, it may seem bold, but there is much truth in the statement that the greatest enterprises of the present day are the results of wise utilization of geographic knowledge.

It is to the astronomers and mathematicans, glued to their telescopes or buried in their complex calculations, to whom we must go for knowledge of the magnitude of the earth, of ways of locating points, of reasons for climatic conditions, and day and night. And so geography, as a science, is related to their subjects. Probably the plains of Chaldæa and Babylon were the primal seats of observative astronomy. For there the unbroken plains of Mesopotamia could not arouse enthusiasm, but the phenomena in the heavens, changing with the days and the seasons, would most assuredly attract attention. Besides, the level expanses and the clear atmosphere gave excellent opportunities for observation. In the matter of map making, the basis for an understanding of distribution finds its foundation in a knowledge of latitude and longitude. Therefore the geographer is indebted to the mathematical astronomer for the graphical representation of the earth. We can not understand the make up of the earth, the so-called "mineral kingdom," unless we deal with chemical materials. It is the laws of physics which enable us to theorize about and understand the workings of many geologic processes, as mountain formation and volcanic activity. It is indeed obvious that physical geography rests in an intimate relation with these sciences; so much so, that certain phases of that study are termed geophysics and geochemistry.

In botanical fields such questions as these "What determines the flora of the steppes?" "Why are some regions treeless and others grassy?" "How is it that the same alpine plants are found on widely separated mountains and not in the intermediate area?" "Why is the cactus provided with water storage organs?" "What are xerophytes, hydrophytes, mesophytes?" These and infinitely many more questions of a similar nature will find their adequate answers only when based upon a knowledge of physical conditions and climatic facts.

In the study of animal life we do not find so direct a dependence upon geographic conditions as in that of plants, just as among men of to-day the dependence upon immediate environment is less marked than in the life of their primitive ancestors, largely because of the "power of locomotion." However, the mere existence of zoogeographical maps shows that there is, nevertheless, a distinct and important relationship. One finds that species and their distribution are determined largely by food, climate and physical conditions. The mountain goat, the camel of the desert, the river beaver, the wading and swimming birds, the antelope of the plains, the apes of the jungle, the reindeer and polar bear in the arctic, the coral in the warm seas—many of their adaptations are determined by the geography of their homes.

In the study of the highest of animals the same influence is of remarkable importance in the shaping of his character and habits. Why does the African have as occupations, hunting, fishing and modest kinds

of agriculture? Why are the Negroids more advanced in culture than the true blacks? Why are the Thibetans pastoral? Why did the Incas represent a superior American type? How have peoples been influenced by the presence of a great river, a vast desert, a yielding mountain, a tundra waste? These questions, and many others relating to man's habits and culture, occupations and history, are intimately associated with geographical considerations.

In the history of medicine and hygiene one can trace, likewise, an interesting connection. Where do bacteria flourish? Where have developed the malignant fevers? The amount of ozone in the air, the amount of moisture, which lessens or raises the rate of evaporation of the body, thus tending to raise or lower the temperature of the blood, is a relevant consideration here. In hot climates bodily activities are lessened because less internal heat is required to maintain the blood at its normal temperature; tissue changes go on at a much slower rate, and these include processes of nutrition. The amount of perspiration, the color of the blood, the color of the skin, have geographical significance, because of the varying action of the liver in various localities.

The relationship of geography to thought can, likewise, be but briefly touched upon here. Psychology, according to James, "deals with states of consciousness as such"—with all states of consciousness—that of the child, the criminal, the lover, the workman, the poet; and in so far as geographical conditions may affect a state of consciousness, to that extent does the geographical factor have a bearing upon psychology. And indeed this factor is quite as important in certain respects as other factors of heredity, physiological constitution, immediate environment. James says: "Mental facts can not be studied apart from the physical environment of which they are cognizant." Strachey writes: "By the influence and study of external nature are found and developed man's emotional, intellectual and moral faculties. The emotions created in the mind by the vast extent of the ocean, the ever-moving surface, the broken outlines of land and sea, the richness and luxuriance of the vegetable clothing of the earth, the never-ceasing transformation of the clouds as they float overhead, the large serenity of nature at rest, and the overwhelming violence of her convulsions, are, even though not consciously, the source of many psychological attitudes." Indeed, the states of consciousness of peoples may be viewed, in a way, according tc geographical conditions. At the sea, mountain dwellers, peoples living in fertile valleys, people inhabiting regions of volcanic or atmospheric disturbances, the desert tribes, or peoples on beautifully luxurious lands —we find their psychological attitudes individually stamped. If typical individuals from such localities were examined, what a range we should find in imagination, optimism, attention, superstition, emotion, habit—

all provinces of psychology! Occupations affect mental states to a great extent, and these often depend upon geography. Health, often determined by drainage, swamps, ozone—how well do we know to what extent it can make or unmake our minds!

Philosophy, which may be briefly defined as an attempt at formulating the universe, utilizes the material results of all fields of knowledge and science, and, in so far as these are related to geography, in so far is philosophy also associated. For the names of philosophers who have been influenced by geographical problems and conditions, one has but to turn the pages of the history of geography, and see the names of Thales, Aristotle, Pythagoras, Ptolemy, Bacon, Ritter, Tyndall, Darwin, Comte. What can, and has, more radically shaped theories concerning the ultimate and the universe than the attempts at the solution of such problems as uniformitarianism, diastrophism and vulcanism?

Religions may not have had their *origins* in natural phenomena, yet the influence of these has often played a wonderful part. From the Himalayan austerity, the solitude of tropic forests, the unmastered floods of great rivers—from such tremendous natural phenomena came the Hindoo religion, a nature worship tinged with the melancholy of future oblivion. In Hindoo mythology the lofty mountains are invested with great sanctity and thousands of pilgrims journey year after year to the holy sources of the Ganges. From the cruel desert came the idea of Mohammedanism, of eternal bliss, an unending dream of sensuous delight attained by the faithful after the privations of a desert life. Ancient Jewish religion was much affected by the geographical factor. Where, too, did the puritans dwell and what was the type of their religion? And how has commerce, born of a geographic source, influenced the religions of men?

J. A. Symonds says: "In their early ignorance of cause, the Greek wondered at everything. When thunder terrified them they attributed their own nature to the phenomenon, and they conceived of Heaven as a vast body which gave notice of its anger by lightning and thunderings. Their sun was called a shepherd, in the early myths, and the clouds his sheep. It was easy for them to make a god of the sea—a husky-voiced and turbulent old man whose form none might clearly know because he changed so often and was so secret in his ways, who shook the earth in anger and had the white-maned billows of the deep for horses." All earliest religions at least *had* their nature worship. The rain made food grow; the sun gave warmth; the thunder-storms could put an end to a long drought. Then, there is a minor nature worship that deals with rivers and springs, with trees and groves, with rocks and stones. The spring was haunted by nymphs, the oak inhabited by a dryad. The Nile and the Ganges were holy. England is full of "sacred hills" which once received prayers and offerings. High places were hallowed in all lands.

In the fields of music, literature and art do we find the psychological attitude greatly influenced by geographical environment. Music's origin must be looked for in natural causes. The elements of all music exist around us, in the sighing of leaves, the gentle monotone of the winds, not less that in the roar of the ocean or the impressive tones of thunder. Earlier peoples imitated these sounds. And, where climatic conditions were good for the throat, singing qualities were developed. Where external conditions were not good for the throat there was a greater amount of inventing rude and noisy instruments. Brinkton says: "The use of noisy instruments recalled the voices of pealing thunder, the mad rushing waters and the wailing of the winds." Early music went hand in hand with the dance, which was, in turn, largely developed in warm climates and on fertile soils. The Esquimaux savage does not sing and dance as the tropical ones, nor does singing come from the people of the frozen tundra save of the poorest sort. Most Hebrew music was strangely harsh; many of their instruments, tabret, buggag, cymbal, pipe, shawn, chiefly wind and percussion instruments, meant *noise* with piercing effects. For, unsettled "dwellers in tents" as they were, this rough element was unavoidable, for, in moving about they came into contact with the rough elements of nature—storms, sea, winds. The Hebrews who were not "dwellers in tents" had, on the other hand, beautiful music—divine gratitude to Jehovah. The Romans had no music, because they were enormously successful commercially, because of their geography, and war and conquest were their first considerations. Something of the same is true of America to-day. Too anxious to utilize to the fullest extent her geographical wealth, she borrows music; chiefly from the negro. Folksongs, one of the truest types of music emanate from the geographically determined life of peoples. All nations had their songs to the soil, to the flock, to the soldiers' march through plain and mountain, had songs of the fisherman, the sower, the reaper. No doubt Russian music owes much of its melancholy and plaintiveness to the great mournful steppes. Why did the violin develop in Italy? Because it, of all instruments, resembles the human voice which was revealed to the Italians. The great German musical names, Beethoven, Mozart, Schubert, Haydn, Handel, Bach, come from *southern* Germany and were influenced by the singers of Italy.

Art, with civilization, seems to have arisen in the three great river basins of the Nile, Tigris, Euphrates, where the people had plenty of comfort and time to satisfy their desire for beauty. The amount of coarse, hard, massive rock available no doubt influenced the colossal architecture of Egypt. Chaldæa is a stoneless country, therefore its arts depended upon the nature of the clays. They, the Chaldæans, invented the potter's wheel—the beginning of a great field of art and industry—ceramics. Art of two dimensions, so to speak, painting, tapestry and

embroidery, has been probably more affected by geographic environment than any other forms. Commerce had a distinct influence here. The crusades brought the new world into contact with the east, and European manuscripts became beautifully illumined after oriental style. Climate, here, too, exerts no little influence. In dry, clear countries the people can see great distances, everything stands out in bold relief, and paintings are apt to be very bright in color, quite different from the work in moist, foggy lands. The Japanese, Chinese and Hindoos possess a natural artistic skill probably greatly determined by their geographical wealth—gold, metal, precious stones and ivory, the silk-worm, and the many vegetable paints and dyes that could be made from the soils. The making of carpets and tapestries goes hand in hand with such climatic conditions as will produce wool and silk. The pearl carvings are most beautiful among people living near the warm waters of the Pacific and Indian oceans. There is a great predominence of yellow and red in Indian designs—because iron compounds are plentiful in the earth. The refinement of Greek detail would never have been possible without her fine marble quarries. Indeed, climate and the prevailing materials in any country determine much the character of the finished building. The towers, minarets, fine tracery and carving of the cathedrals and churches of Europe owe their existence to a great extent to the use of soft limestone and caenstone. There are flat roofs in dry countries, pitched roofs where there is little rain, and steep ones in snowy regions.

In dealing with literature in this connection, people may shake their heads. If one attempts to trace the influence of sea, mountain, desert, river, seasons, climate, they might say "Of course. That is nature. Of course our literature reflects those things." But, if literature were permeated with expositions of and similes concerning the mechanics of solids and fluids, would it not be interesting at least to trace the relation between physics and literature? The first literary themes of peoples are always songs of the sea, the river, the night, the mountain. In the songs of Indian, American and African savages there is an endless maze of themes to the winds and erosive forces of nature. Many of our literary monuments are merely recitals of geographical exploration and discovery—from Ulysses to Gulliver. The seasons have been sung by Shelley and more others than there is space to name. All stories of *Wanderlust* are associated with the spring time. Literature of specific areas is definitely stamped. Italy, because of her geographic condition, has been a distinct influence not only upon her own writers, but upon all writers who have journey there—Bryon, Goethe, Shelley, Browning, Keats, Milton. The influence of the north—how absolutely can we trace it! Beowulf is a mirror, almost, of the grimness of the north. Fiona Macleod, Ibsen, are essentially of the north. Pick up *Brand*. Where else could it have been produced? The desert, the river, the sea, the mountain, have been inspirations of many literary efforts.

All this may seem as much a "mere rush of detail" as that spoken of as characteristic of the geography of our school-days; but the details are of a different nature—more vital and of more human interest. Though the field is, I grant, entirely too large to be covered in a brief paper, yet, to make of geography not merely a collection of bald facts, but a study most intimately associated with and related to the fields of human activity—commerce, industry, history, science, thought, music, literature and art—that is what I mean by a "philosophy of geography."

CHINESE MATHEMATICS

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NO one who is interested in China and in things Chinese, and no one to whom the evolution of thought appeals, can fail to appreciate the recent articles by Dr. Edmunds, the learned president of the Canton Christian College, upon science among the Chinese.[1] His extensive travels in all portions of the country, his own scientific attainments, his wide acquaintance with Chinese scholars, his connection with numerous scientific expeditions, and his official position at the head of one of the most progressive colleges in the country, all qualify him to speak as one having authority.

It is, however, quite natural that one whose tastes are not primarily in the line of mathematics should fail to do justice to the work of Chinese scholars in this field. It is true that this work was not of a high order, and yet it must be said that it ranked with that which was being done in other branches of science, and had not the relatively low standing that would be inferred from Dr. Edmund's statements. These statements are summarized in the following:

> The study of arithmetic has attracted attention among the Chinese from early times, and notices found in historical works indicate some treatises[2] extant even in the Han Dynasty (206 B.C.–A.D. 214), followed by a great number of general and particular works down to the Sung Dynasty (1020–1120 A.D.). The Hindu processes in algebra were known to Chinese mathematicians, but though studied even after intercourse between the countries had ceased, these branches made slow progress down to the end of the Ming Dynasty (A.D. 1368–1644).[3]

Now as a matter of fact there is a good deal known of the mathematics of China in the pre-Christian era, and in certain respects their algebra in the Middle Ages was much in advance of that of their European contemporaries. Furthermore, this algebra appears to have been indigenous to China. While Sanskrit was known there very early, and by about 800 A.D. was even taught in Japan (through the writings of the great scholar, Kōbō Daishi), there is nothing in the mathematics of either country that shows dependence upon any known works of Hindu scholars. On the contrary, it would seem that Brahmagupta, who

[1] The Popular Science Monthly, Vol. LXXIX., p. 521; Vol. LXXX., p. 22.

[2] Misprinted "treaties" in the original.

[3] Vol. LXXIX., p. 527. Substantially repeated in Vol. LXXX., p. 30.

wrote in Ujjain in the seventh century, was indebted for at least one of his problems to the great Chinese classic, the Chiu-chang Suan-shu.

Of the scholars whose contributions to mathematics were noteworthy, it will suffice to mention only a few, although it should be stated that these are the greatest of their respective periods so far as we now know.

No one knows how far back the Chow-pi goes. It purports to be a dialogue between Chow Kung and Kao (or Shang Kao) and to have been written c. 1100 B.C. Wylie[4] translates part of it, and shows that it contains a reference to the Pythagorean proposition and to a primitive trigonometry. It has long been known that the discovery of Pythagoras was the proof and not merely the fact, for the latter is mentioned in Egyptian writings before his time, and in Hindu works that probably antedated him, so that it is not surprising to find it in China.

Chang T'sang, who died in 152 B.C., restored the Chiu-chang Suan-shu, or Arithmetical Rules in Nine Sections, for the antiquity of which, in its original form, great claims are made.[5]

From the standpoint of mathematics the most interesting features of this work are the use of negative numbers, the trigonometry of the right triangle, and the fang-ch'êng process. The last named constituted one of the nine sections and concerned the solution of simultaneous linear equations. This would hardly be worth mentioning except for three reasons: (1) We have nothing of this kind in the algebra of Europe as early as this; (2) from this method of the Chinese came, by direct descent, the early Japanese method that led by obvious steps to the invention of determinants by Seki before the idea occurred to Leibnitz;[6] (3) the method for the extraction of roots led Ch'in Chiu-shao, in 1247, to anticipate Horner's method, as will presently be shown.

Sun-tsŭ, whose date is unknown, but who probably lived in the third century of the Christian era, wrote a work on arithmetic in which he set forth the process known as t'ai-yen ch'iu-yi-shu, a form of indeterminate analysis that was afterwards employed with much success. It

[4] "Chinese Researches," Shanghai, 1897, Part III., p. 163.

[5] From the preface of the edition by Liu Hui (third century A.D.) we have this statement: "After the terrible Ching had burned the books, the classics and (works on) arts were dispersed and lost. Later, in the Han Dynasty, the Duke of Pei-ping, Chang T'sang, and also Ken Shou-Ch'ang (Ching Ch'ou-ch'ang) a Commissary agent, were well known because of their talents in (the domain of) number. T'sang and this other, because of the incompleteness of the ancient writings, revised (by adding to and taking from) the work. So did each claim. Upon comparing the contents their works were seen to differ from the original, but the subject matter is much alike."

The origin of the work is often asserted to go back to c. 2650 B.C.

[6] See T. Hayashi, "The Fukudai and Determinants in Japanese Mathematics," in the *Tōkyō Sugaku-Bulurigakkwai Kizi*, Vol. V. (2), p. 254.

is this general form to which we give the name of Diophantine analysis, although Diophantus probably lived after Sun-tsŭ. One of his problems is as follows: "Find a number which when divided by 3 leaves a remainder of 2; when divided by 5 leaves a remainder of 3; and when divided by 7 leaves a remainder of 2." At a considerably later date such problems were common in Europe, and were evidently imported from the East.

Tsu Ch'ung-chih (428–499)[7] certainly deserves mention if any standing is to be accorded to Metius in the history of mathematics, since he discovered the latter's value of π some twelve centuries before it saw light in Europe. About two hundred years before him Liu Hui[8] (in 263 A.D.) had given the value $^{157}/_{50}$ (= 3.14), and Wang Fan had suggested $^{142}/_{45}$ (= 3.1555 . . .). But Tsu Ch'ung-chih, working from inscribed and circumscribed polygons exactly as Archimedes had done, showed that the ratio lay between 3.1415926 and 3.1415927. As limits he fixed upon $^{22}/_{7}$, the Archimedes superior limit, and $^{355}/_{113}$, the value found by Metius. How Tsu came upon these limits we do not know, since his work (the Chui-shu) is lost, but it is possible, as Wei[9] asserts, that he knew something of infinite series.

Wang Hs'iao-t'ung, who lived in the first part of the seventh century, wrote the Ch'i-ku Suan-ching, in which appeared an approximate method of solving a numerical cubic equation. At a later period this would not be significant, but when we bear in mind that this is two centuries before Al Khowārazmi (c. 825) wrote the first book bearing the title "Algebra," and some three hundred years before Alkhazin (c. 950) and Al Mohani were working on this simple cubic, it is interesting.

The golden era of native Chinese algebra was the thirteenth century, made notable by reason of the works of three men living in widely different parts of the empire. Of these, one was Ch'in Chiu-shao,[10] who wrote the Su-shu Chiu-chang in 1247. This must always stand out in the history of mathematics as a noteworthy contribution, for here we find the detailed solution of a numerical higher equation by the method rediscovered by Horner in 1819, the only essential difference being in the numerals employed. As already stated, Ch'in merely elaborated the process for finding the square and cube roots as laid down in the Chiu-chang Suan-shu some fourteen centuries earlier, and this raises the question, How did Leonardo Fibonacci of Pisa solve the numerical equation of which he gives the root to such a high degree of approximation? He wrote his work in 1202. Did he have some

[7] Not the sixth century, as Cantor states.

[8] Lew-hwuy.

[9] The Chinese historian of mathematics.

[10] Tsin Kiū-tschau, as Cantor has it.

hidden knowledge that had come from the Far East—some work upon which he as well as Ch'in Chiu-shao was able to build? It is one of the many questions in the history of mathematics that still remain unanswered. That the problem of the couriers, commonly attributed to the Italians, is also found in Ch'in's work, is likewise significant.

Li Yeh[11] (1178–1265) composed two algebras, the T'sê yüan Hai-ching (1248) and the Yi-ku Yen-tuan (1259). Curiously enough, both works relate solely to the method of stating equations from the problems proposed, and not to the method of solving these equations. He also applied algebra to trigonometry, however, thus anticipating in some measure the European analytic treatment.

Chu Shih-chieh, living also in the thirteenth century, wrote his Suan-hsiao Chi-mêng in 1299, and his Szŭ-yüan Yü-chien in 1303. In these two works the native algebra of the Chinese may be said to have culminated, the methods of his immediate predecessors being here brought to a high degree of perfection. In the latter treatise the so-called Pascal triangle is found, and Chu mentions it as an ancient device that was used in solving higher equations. This was some three hundred and fifty years before Pascal (1653) wrote upon the triangle.[12]

Kuo Shou-ching (1231–1316) introduced the study of the spherical triangle into China, although for astronomical purposes only. His work was apparently influenced by the Arabs, and so can hardly be called a native Chinese production.

No mention has been made of a work known as the Wu tsao,[13] written in the fifth century; of the Suan-ching, one of the great treatises on Chinese arithmetic; nor of Chin Lwan who wrote the Wu-king-suan-shu in the seventh century; nor of his probable contemporary, Chang Kew-kien, who also wrote a Suan-ching, nor of several other well-known writers, because these men contributed nothing to the science of mathematics. They were makers of text-books with a genius for exposition, but without a genius for mathematical discovery.

Enough has been stated, however, to show that the Chinese probably found out for themselves certain truths of geometry, and among these the Pythagorean theorem; that they early developed a plane trigonometry; that they did good work in approximating the value of π; that they possibly did some original work in infinite series; and that they certainly led the world at one time in algebra. It is probable that we shall soon see the publications of translations of the writings of the early mathematicians of China, or at least such a study of their works as Endō, Hayashi, Kikuchi, Fujisawa and Mikami have made of the native Japanese treatises. When this comes to pass we may possibly

[11] Li Yay, as Cantor has it.

[12] It seems first to have appeared in print in a work by Apianus, 1527.

[13] Five sections.

be able to appreciate the contributions of Chinese scholars even more highly.[14]

[14] The writer is indebted to various works upon Chinese science, and to the help of a number of scholars. It will possibly assist some reader if a few of these authorities are mentioned: A. Wylie, "Chinese Researches," Shanghai, 1897, Pt. III., p. 159; M. Courant, "Bibliographie Coréene," Paris, 1896, Vol. III., p. 2; J. Legge, "Chinese Classics," 2d ed., Vol. I., p. 4; H. Cordier, "Bibliotheca Sinica," Paris, 1905–6, Vol. II., cols. 1372, seq.; A. Vissière, "Recherches sur l'abaque chinois," in the *Bulletin de Géographie*, Paris, 1892; S. W. Williams, "The Middle Kingdom," edition of 1895, Vol. I., Chap. XI.; A. Wylie, "The Mongol Astronomical Instruments in Peking," in Vol. II. of the "Travaux de la 3e. session du Congrès internat. d. Orientalistes"; A. Wylie, "Jottings of the Science of Chinese Arithmetic," in the *North China Herald* for 1852; M. L. Am. Sédillot, "De l'astronomie et des mathématiques chez les Chinos," in the Boncompagni *Bulletino*, Vol. I., p. 161; Y. Mikami, "Mathematical Papers from the Far East," Leipzig, 1910, p. 1; Y. Mikami, "A Remark on the Chinese Mathematics in Cantor's Geschichte der Mathematik," in the *Archiv der Mathematik und Physik*, Bd. XV. (3), S. 68, and Bd. XVIII. (3), S. 209. There are also the various histories of mathematics, including those of Montucla (2d ed., tome I., p. 451) and Cantor (Bd. I.). The writer is also indebted to Dr. W. A. P. Martin and to Mr. Mikami for personal communications relating to the subject. He is also largely indebted to his pupil, Professor T. H. Chen, of Peking, for numerous translations, including extracts from the Chinese historian of mathematics, Mei Wuh-ngan, and a translation of the entire T'sê yüan Hai-ching (1248) of Li Yeh.

THE PRACTICAL BASIS FOR REPUBLICAN INSTITUTIONS FOR CHINA

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A RECENT issue of a Chinese daily published in Shanghai records this incident: The venerable teacher Chang, a man well known and respected in his community, was stricken with a mortal disease. Three days before his death he requested his eldest son to shear off his queue, explaining that "though he had worn this badge of servitude to the Manchu usurpers for over three score years, now that the day of freedom was at hand, he desired to appear in the other world, not as a slave, but as a free son of Han." The native press, which is almost entirely revolutionary in its sympathies, refers to the contending armies as the "patriots of Han" and the "Manchu slaves." The revolutionary manifestoes run in the name of the "People of Han," and some bear date from the "founding of the Han Dynasty."

These references all hark back to the golden age of Chinese history, when the house of Han, of pure Chinese blood, wielded the vermilion pencil in the ancient capital of Nankin. Their pertinency in the present struggle for constitutional liberty is further emphasized by the fact that under this dynasty the Chinese received their first charter of rights. In 206 B.C. the emperor Han Kao Ti, as wise, far-seeing and gracious as our own King John was stubborn and recalcitrant, made what is known in Chinese chronicles as "the Tripartite Bargain with the Elders of the People." This oriental Magna Charta is summarized in the terse Chinese ideographs as follows: "(1) Death for homicide; (2) compensation and imprisonment for wounds and robbery; (3) all else left to the people."

From that day to this the "bargain," particularly the "all else left to the people," has epitomized the Chinese conception of the functions of government. There have been many codifications of the laws of the empire, nearly every dynasty having signalized its accession by a new code. One feature, however, characterizes all this legislation—the entire body of the law is criminal. What concerns the people in their business and social relations has, in the words of the charter, been left to the people. Search the "Ta Tsing Leu Lee," or the "General Laws of the Imperial Dynasty of Tsing," as the present code is known, and there will be found a most careful classification of crimes, one, moreover, which faithfully reflects the ethical standards of the people. In

fact, much of it reads like a paraphrase into legal terms of the moral teachings of Confucius. To this is added a minute gradation of punishments. But in all the thirty-six volumes in which the code is usually published there is hardly a reference to contracts, and no mention whatever of negotiable instruments, partnerships, or to any of the other branches of civil law.

It is in this broad field of private rights and liabilities that the genius of the people for organization and regulation displays itself. Aside from literary pursuits, the absorbing interest of the Chinese is trade, and in this department they brook no interference from governments or authorities. Commerce is closely organized. In a large commercial center the traders in every staple have their association, the visible evidences of which are the large, substantial guildhalls. In Shanghai, for instance, will be found a piece-goods guild, an opium guild, a silk guild, a bankers' guild and numerous others of lesser importance—in fact, no class in China seems to be so ignorant or so poor as to be wanting in some organization for the protection of its members. There is even a beggars' guild.

The guilds are something more than we might infer from the term. They have an overshadowing prestige. Some years ago the viceroy of one of the coast provinces attempted to levy an additional impost on salt. The merchants protested. The viceroy was obdurate. Not a catty was sold until the distress was such that he was compelled to yield, and shortly after memorialized the throne to be relieved of his official duties "in order that he might visit his parents." Negotiable paper has been in use in China for many centuries. The well-defined usage on this subject is the outgrowth of the regulations of the bankers' guild. More recently, the law of insurance has been provided by the underwriters' guild, that of transportation by the shippers' guild, and so on. In fact, it has been said by an authority on Chinese business customs that if the by-laws of all the various guilds could be gathered together, the collection would constitute not only a logical, consistent commercial code, but one far better adapted to its purpose than any that could be produced by the ordinary processes of legislation.

Commercial disputes very rarely come before any court for adjudication. Between members of the same guild such matters are decided promptly, finally and satisfactorily by the guild itself. Differences between members of independent guilds are referred either to a joint committee, or to a third body for arbitration. If a point involving commercial usage comes before a magistrate it is usual for him to call for a ruling from the proper guild.

The aloofness of the government is further illustrated by the laws covering marriage and divorce. The code defines with exactitude the relationships in which marriage is unlawful, but no such thing as a

license or a public ceremony is required. It is left to the individual to make his matrimonial choice within the limits provided by law, and then to celebrate his nupitals in his own way. Should he mistake his rights and marry within one of the prohibited degrees he is subject to punishment. The same attitude is maintained towards divorce. The code specifies the grounds for such a separation, enumerating besides those recognized by us, such delinquencies as "talkativeness," "envious and suspicious temper," "disregard of the husband's parents." Upon any of these the husband may give his wife a bill of divorce. Should he, however, perchance misjudge his own case, he is subject to eighty blows of the bamboo.

An interesting feature of the Chinese ethical system which the code brings into prominence is the idea of mutual responsibility. It is provided that "when the parties to an offense are members of one family, the senior and chief member of that family shall alone be punishable; but if he be upwards of eighty years of age, or totally disabled by his infirmities, the punishment shall fall upon the next in succession." By virtue of this principle, the burden of criminal responsibility has been known to descend from father to son for generations while a litigation was taking its leisurely way through the courts to the Board of Punishments in Peking, and finally to the Emperor, until in the end the penalty fell upon some person born long after the event. Of the same character is the mutual responsibility of persons residing in the same neighborhood. A typical case is where a parricide having been committed, all the houses in the vicinity are demolished, the theory being that the residents have been culpable in failing to exert a better moral influence over the criminal.

A feature of Chinese society which makes for democracy is the almost total absence of such a thing as a hereditary nobility. For over two thousand years the descendants of Confucius have been honored with the title of "Dukes of Kung," and in the same manner the descendants of the famous sea-fighter Koxinga have been distinguished with a hereditary title. But with these exceptions, and with the exception of the imperial family, the only aristocracy recognized generally in China is based on learning, and this is open to the humblest and most powerful upon like terms. The tourist in the provincial capitals is usually shown the examination halls—rows upon rows of tile-roofed sheds divided into cells not more than six feet square. Here every three years the candidates for literary degrees gather from all parts of the province.

Until recently the Chinese classics have been the subject of all examinations. The chancellors selected at random a phrase from the works of some ancient moralist which the students were required to expand into an essay framed on the stilted canons of Chinese literary

style. In 1898 the late Emperor, Kuang Hsu, realizing the futility of such exercises, abolished the "eight-legged examination essay" and substituted modern sciences. This measure found its reaction in the Boxer uprising two years later. The disasters of the frenzy, however, convinced all of the inadequacy of ancient literary lore, and the result is seen in the marvellous intellectual awakening which followed it. Western learning was snatched up with avidity; students were sent abroad; scientific works were translated and published; modern methods were introduced into government schools, whence they are now invading the examination halls.

From the literary class recruited through the examination system the positions in the government are filled. The man with a degree at once becomes one of the "headmen" of his village, and usually, by common consent, holds the office of *ti-pao,* which corresponds to that of our justice of the peace and notary combined. He authenticates deeds, settles disputes among his neighbors, and acts as their spokesman and representative in all that concerns the higher officials. Or he can attach himself to some official in a clerical capacity, his subsequent rise to the highest positions in the government being dependent upon his industry, diplomacy and political acumen. Such statesmen as Li Hung Chang, Chang Chih Tung, and the present Yuan Shih K'ai, rose from humble stations.

To the advocate of a republican China, the examination system is the strongest argument that can be advanced for his cause. It so intimately reveals the Chinese character. The man who is successful in an examination covers not only himself, but his family and community with glory. The Chinaman is not attracted by the demagogue, but he has a profound respect for the opinions of those who by assiduous toil and severe test have won their way to intellectual honors. He has for centuries been accustomed to look upon these men as the logical repositories of political power.

The provincial assemblies, which have been held in the last two years, proved a revelation to all observers. The discussions were intelligent and revealed a sincere purpose on the part of the members to promote the general welfare. They have proved that the hopes of the revolutionary leaders are far from chimerical. The basis for republican institutions in China is broader and safer than in many other countries that enjoy self-government. The people are by nature and habit industrious, peace-loving and accustomed to self-restraint. In the aggregate of relations and transactions which make up social and commercial life they have suffered less interference than the average American citizen. The great mass of rules governing the relations of men they have formulated themselves, and they have learned, moreover, the sobering lesson of submission to law as the best guaranty of the rights of all.

A PROGRAM OF RADICAL DEMOCRACY

By J. McKEEN CATTELL

THERE is advance towards radical democracy in every nation. In the United States the two political parties have made some progress in recent years in answer to the demands of the people; but this slow and halting movement, falling behind that of Great Britain, should be hastened, either by the formation of a new political party or of a radical section within one of the existing parties. The socialist party might serve as a center of union, if questions concerning the production of wealth and the limitation of individualism can be subordinated to social welfare. The best solution, however, of the existing political situation would probably be the maintenance of the two historic parties, the republican party being frankly devoted to rule by the privileged classes under the leadership of men such as Mr. Roosevelt, Mr. Taft and Mr. Hughes; the democratic party to control by the people with as little individual domination as may be. Twenty reforms in the direction of radical democracy are here indicated. Some of them may appear to be utopian and doctrinaire, but there is not one of them toward which progress has not been made in recent years, not one of them toward which further progress will not be made in the near future.

1. *Universal suffrage, the votes of children being cast by their parents.* The bearing and the rearing of children are so much more important than any other work that the right to vote is in comparison insignificant; but voting would in no way disqualify women for their greater service, and this surely should not disqualify them from voting. Women have long been goddesses, queens, prostitutes and slaves; it is clearly time that they should have exactly the same political, legal and economic rights as men. Women are on the whole more sympathetic, patient, personal, emotional, illogical than men. These traits would probably improve political conditions; but this is almost irrelevant. Universal suffrage is simply the presupposition of democracy. Children are also human beings, and their votes should be cast by their parents. This would give the correct distribution of political power and the basis for a complete political democracy. The substitution of the rights of children for the privileges of property is the greatest advance that can be made by society. The woman or man who has children is that much more of a woman or man and should vote accordingly.

2. *Personal liberty and local government.* The liberty of the individual should be limited only when it interferes with the liberty or the rights of others. The man who has smallpox must be isolated; one who mistreats his children must be imprisoned; the owner of an automobile, the upkeep of which costs more than the support of an average family, should be taxed; because each of them would otherwise interfere with the welfare of others. But legislation to suppress unobtrusive vice, to keep people married who want to separate, to prevent polygamy, and the like, is of doubtful value. The national congress should not do what state legislatures can do equally well, or the state legislature interfere with local government. The inequality and artificial boundaries of the states, the disastrous growth of cities, the heterogeneous and changing population, are among the conditions which make local government difficult. But the nation should not lord it over the states, the state over the county or city, the county or city over its local units, these over the group or family, the group or family over the individual.

3. *The abolition or the limitation of the powers of the constitution of the United States, of the president, of the senate and of the supreme court. Similar limitations in state governments.* The national government being historically a federation of states may need some constitution, but it does not need much of one or one very much. It would be entirely safe for the congress to decide what the nation shall do and what shall be left to the separate states. Great Britain is better off without a written constitution. The scheme of checks and balances is wrong in theory and bad in practise. Men will nearly always rise to the level of the responsibility put on them. The existing lack of responsibility demoralizes the legislature; placing responsibility on the individual autocrat makes, as a rule, a good autocrat; but that is not what democracy wants. The president should be only the executive officer of the congress. The senate is a superfluous nuisance. A supreme court may be needed to decide what the congress intended when it enacted a law, but it is not there to play with the meaning of words or to interfere with legislation. Every outworn constitution and law, every perpetual franchise and charter, should be scrapped. The dead can not be permitted to rule the living.

4. *Government and all its functions to be executed by those most fit, selected by and responsible to the people.* Political democracy does not mean government by the uninformed, but by those best able to serve the people. Delegated and expert government is necessary; it is clearly impossible for the people to consider all the minor measures that must be enacted and all the minor officers that must be selected. The proper condition seems to be for those of a neighborhood to select the men in whom they have from personal acquaintance the most confidence, these

to select a representative to meet with representatives of other neighborhoods for the county or state, these representatives to select the national officers. But this scheme has broken down under the party system and the control which can be exerted by professional politicians and selfish interests. At present representative government has partly collapsed, but the demands of the people will soon be met. In the meanwhile direct nominations, the initiative, the referendum and the recall may be of use. But direct nominations favor notoriety and wealth. The referendum is a conservative rather than a radical measure; it can, however, be used to advantage as an educational method when all are concerned and interested. A commission should be more competent to select a health officer than a plebiscite vote, though it may be that the people would be more likely to be guided by expert opinion than is a temporary autocrat, such as Governor Dix. Great progress has been made in appointments for fitness and in civil service rules. The present unrest and dissatisfaction is not due to worse selections, but to higher standards. Our political organization and our politicians have advanced more slowly than the intelligence and the moral sense of the community.

5. *The payment of all national, state, county and municipal debts. Taxation discouraging private debts.* Freedom from debt is the first principle of personal and domestic economy. It is extraordinary that it should be so completely neglected in the case of public debts. If the socialist party wants municipalities and the state to own the tools of production, the first thing to do is to let them own themselves. Debts are the principal hold of the kleptocratic classes on the community, giving us our system of paper wealth by means of which a small class taxes the people. Temporary war debts can be understood, though nothing would conduce more to peace than the payment of the cost of war as it proceeds. Debts for exceptional public improvements are proper, but they should be paid within a fixed period. Contrary to existing practise, bonds should be taxed rather than stocks. The taxing of evidences of debt would limit borrowing and would return to the people part of the interest fund. The rich would be compelled to invest their money in productive enterprises, where it would be of use and would take risks, leading to its wider distribution.

6. *A national progressive tax on inheritances and incomes as large as can be collected. A progressive tax on corporations. A heavy tax on expenditures involving waste and luxury.* Inheritances and incomes should be taxed by the nation to prevent dodging if the taxes are local. No tax is good, but an inheritance tax is the least objectionable of all taxes. It taxes the dead or at all events those who have not had the property; it is easily and truly collected; it tends to the distribution of wealth. It should be at least half of large fortunes, and larger when

there are no children, or but one or two. An income tax promotes lying, but it should be adopted, and the sworn statements of all incomes and expenditures beyond the average should be made public. No one deserves more than, say, four times the average income. A man's services may be worth more than that, but they are made possible by the organization of society. A progressive tax averaging fifty per cent. on incomes above $5,000 would be desirable, if it could be collected. Every one who spends much more than the average should be placed under the supervision of the state. The connotation of stealing and robbery has been extended beyond force, but it must be further extended. The tax on corporations is the most excellent and radical measure passed by a recent congress; credit for this should be given to President Taft. In so far as large corporations are undesirable, they should be taxed progressively. The remaining income required by the national government should be from import and excise taxes on products the use of which involves injury, luxury and waste.

7. *A local and state progressive tax on real estate and tangible personal property.* State and local taxes should be on real estate and tangible personal property, situated where the receipts from the taxes are used. It is not clear that the increment of value on land belongs to the public more than the increment of value on personal property, but a transfer tax on real estate, based partly on the increment of value, can be conveniently collected and would discourage speculative holding. There should also be a large transfer tax on stocks and bonds, the increment of value being taken into consideration. A progressive tax on dwellings is the most useful of local taxes. A house or tenement, the rental value of which or of whose apartments is under $150 a year, especially if owned by the occupants, might be exempt, while a million-dollar dwelling might be taxed a hundred thousand dollars a year. Dwellings represent pretty accurately the annual expenditures, and a progressive tax is the most convenient way of taxing these. There should be a high progressive tax on tangible personal property that is not the tools of production—on expensive furnishings, pleasure automobiles and the like. Owners might be allowed to place their own valuation on real estate and personal property, the state or any individual being permitted to purchase it at twenty per cent. advance, the property being redeemable by the original owner on payment of this margin.

8. *The conversion of the army into local police forces and corps for engineering work and other improvements. The conversion of the navy into a merchant marine.* We should have the best army for defense and improved police forces if all local police were soldiers, one twelfth of their wages being paid by the nation and one month annually being spent in camps and drills. Idling in barracks is a method for the

promotion of war, drunkenness and disease. The engineering corps, the health service and the commissariat are the most important factors in modern warfare. Engineers, health officers, inspectors of food and others employed by the nation, the states and the municipalities should be at the same time officers in the army and those under them enlisted men. A well-organized and efficient army for defense would thus be maintained at comparatively small expense and be an institution for education instead of for demoralization. The navy should be converted into a merchant marine, carrying a postal, express, freight and passenger service to every port in the world. At the cost of an idle navy five to ten times as many ships and men could be maintained and employed in useful work. In case of war swift ships and experienced men would win over dreadnoughts. Shipyards and factories for armaments and ammunition should be owned by the nation and manned by officers and enlisted men. The army and the navy can be made self-supporting nearly as easily as the postoffice. Fortunately they may be regarded as temporary institutions.

9. *Limitation of foreign treaties and representatives. No interference with foreign nations, except for humanitarian reasons. The submission of all international questions to arbitration.* We are warned against entangling alliances; all treaties are such to a certain extent, and in most cases are at present useless and dangerous, though international courts and agreements may in the future become desirable. Let us be just and generous to all nations and to all foreigners, and trust them to be the same to us. If they are not, those who see fit to deal with them should take the risks. Missionaries, traders and travelers should be subject to the laws and ways of the lands to which they go. Secret diplomacy has no place in a democracy; the social snobbery of an ambassador is disgusting; his political office is made useless by the cable. Arbitration treaties are unnecessary; but we should be ready to submit all questions to arbitration. There should be no interference with foreign affairs, except for clear humanitarian reasons, approved by neutral and disinterested nations. We shall be better off if South America is peopled by Germans and Russians as well as by Spaniards, Portuguese and Indians. War is avoided by delay. It should not be possible for the president to involve the nation in war, and no war except for defense should be undertaken before the question has been submitted to a plebiscite vote and carried by a majority exceeding one half of the population.

10. *Colonies and dependencies to be held only for the benefit of the peoples concerned and with their consent.* The vigorous and prolific races will supplant those which are decadent; but wars of conquest are now equally injurious to the conqueror and to the conquered. In the past it was necessary for an expanding population to subdue savage

races and sparsely populated regions, but with the exception of Africa such conditions no longer obtain. Races must work out their own destiny. India can not be ruled indefinitely for the support of the younger sons of the upper classes of England. Conditions have been inherited from a barbarous past, and we must make the best of them. But hereafter no race and no section of a nation should be held in subjugation by force, except for humanitarian reasons, which appear sufficient to neutral nations. Fortunately our own complications are practically limited to the Philippines and are not insoluble. Political conditions and social relations should be independent of race and color.

11. *Gradual reduction of the existing tariff.* The protective tariff has been one of our most disastrous adventures; the present opposition to it is a gratifying sign of national health. The tariff has not only caused boundless political corruption and waste of economic resources, but has forced people from a healthy life in the country into the cities, the manufactories and the mines, and has supplanted our native population with immigrants. It is largely responsible for inequality of wealth and industrial slavery. To meddle with the schedules of the tariff will cause further corruption and industrial disorder. It should be abolished gradually by a five or ten per cent. reduction annually on all schedules. Desirable import taxes can be separately imposed.

12. *The government to regulate the value of money, but not to engage in borrowing or lending.* If any one supposes the first part of this proposition to be due to Mr. Bryan, he is referred to the constitution of the United States. Mr. Bryan is essentially conservative, as are the people; but in his sympathies at least he is the best leader for a democracy that the country has had since Lincoln. In the bimetallic campaign he was not wrong in his aims, but only in his calculations. The present increase in prices—the cost of living is another matter—is in the main due to the depreciation of the value of gold, and is evidence of the inadequacy of a monometallic standard. The net result of this depreciation may not be bad, as it decreases the wealth of the passively exploiting classes, though it increases the wealth of the actively predatory classes and is unjust to those living on wages and salaries. But an unstable monetary standard is a bad business. The nation should fix a standard of value, based on the more important products of the country, and be prepared to redeem its paper currency in these products. It would not of course need to redeem it; the property of the nation is ample physical security. We have in fact a paper currency—checks and drafts being its most important part—but we need a fixed standard of value, first national and then international. A national bank is as objectionable as are the other activities of the author of the scheme. Postal savings may be of use as a temporary piece of paternalism, but should not be permanent. The banks, the bankers,

Wall Street and the money power should be controlled by progressive taxation.

13. *Complete reform of the courts.* Neither Mr. Taft nor Mr. Roosevelt is a radical or a democrat, though both to a certain extent—the latter increasingly—have followed the lead of the people. Mr. Taft is called a conservative and is unpopular because he regards the courts as sacrosanct; Mr. Roosevelt is called a radical and is popular because he attacks them. This is a healthy symptom. The injustice of courts established to promote justice is monstrous; their favoritism of the rich is intolerable. The domination of the legislature by the courts, their powers of injunction, imprisonment for contempt, convictions and acquittals on technicalities, appeals on technicalities, delays purchased by wealth and fines as an alternative to imprisonment, expert testimony, insanity pleas, false charges and pleas by district attorneys as well as by hired lawyers, all this must be swept away even at the risk of temporary disorder. The judges who decide that an employers' liability law passed by the legislature is not due process of law should be impeached. If needs be lawyers should be disqualified for a time from becoming judges or appearing at court. The domination of the lawyer and of his point of view in political life is most unfortunate.

14. *Free medical service and the promotion of health in every way that does not interfere with the freedom of the individual.* The conditions in medicine are not so bad as in law, but they are very bad. Great Britain is just now setting an example in medical reform which we should follow. It is better to promote health than to try to cure disease. All medical and surgical service should be free to those having less than the average income; no hospitals or clinics should be conducted as charities. Private and endowed philanthropy—except as a temporary expedient—is a public nuisance. The rich should be able to obtain the best medical and surgical services only in or from the hospitals, and should be charged in proportion to their means, the fee going to the hospital, not to the physician, who should have a fixed salary. The freedom of the individual, whether to carry on vivisection, to go without vaccination, or the like, should not be interfered with without good cause. Education, publicity, correct labeling and awards for damages are the best ways to prevent malpractise, fake medicines and adulterated foods. A billion dollars a year spent on the suppression of disease and the promotion of health would be a profitable investment, if men can be found to do the work.

15. *Old-age and disability pensions. Subsidies for all children.* People must be supported in old age and when disabled or submerged, and this should be done by the state as soon as we can manage it. It is not for the benefit of the state or the race, but is a reasonable demand on humanity. The necessities of life should be supplied to every one

and those who earn more should have more. Subsidies to children are for the benefit of the nation and the race as well as of the individual. Those we now give, such as free education, should be extended, until the cost of bearing, supporting and educating each child is borne equally by every one. The means for a healthy life should be provided for every child, and all possible opportunities for well-born and promising children. The care of children is dominant above every other privilege or duty of the individual and the state. Children are now supported by the resources of society, and with our existing wealth two or three times as much could and should be spent on each child. When the state attends to this the taxation will be large, but not unmanageable. The chairman of the committee on ways and means of the house of representatives estimates that a one-per-cent. tax on incomes above $5,000 will yield $60,000,000. The wealth wasted or saved from large incomes would consequently yield $200 for each child under sixteen. This sum will suffice, temporarily, if the locality provides schools, books, meals, medical service, etc.

14. *A maximum day's work of eight hours and a minimum wage of two dollars. No child labor, except what is of benefit to the child. A maximum annual income for an individual of $5,000; a maximum inheritance of $50,000.* Those who can't or won't work must be provided with the necessities of life. Those who can and will work should have not less than two dollars a day at the present purchasing power of money, and work must be provided for all. Eight hours is a day long enough for employment, but more can be accomplished by those who wish to devote more hours to useful work. Child labor, except for the benefit of the child, is absolutely intolerable. The average annual income of those who work is about $1,000 in Great Britain and in the United States. If idleness and waste can be eliminated it will be about $2,000, including women who care for the home. Under existing conditions, if the minimum wage is $600, an ample margin is allowed for competition, and every one can save money. The average wage being $1,000 there may be numerous individual incomes as large as $2,000 to $5,000, or $4,000 to $10,000 for a family. This is as large as any income should be, so long as the average income is $1,000. Each individual would in addition have by inheritance his home and his tools of production, his share of the wealth held by the nation, the state, the county, etc. But the inheritance of no individual should exceed $50,000. Incomes would be doubled by the suppression of idleness, mismanagement and waste and can be again doubled by the further advances of the applications of science. This fourfold increase of wealth will probably be available before any such partial equalization by taxation as is here proposed becomes feasible. Room can be left for competition and savings so long as such incentives are needed. We

may hope, however, that the game of life will become so interesting that it will not be necessary to play for stakes.

17. *The homes and tools of production to be owned by those who use them. The excess wealth to be owned by the locality, the state and the nation. The enterprises to be operated in the manner that gives the greatest economic efficiency and social welfare.* The homes should be owned by those who live in them—tenements and apartments, as well as city and country houses. Taxation of homes should be adjusted so that homes of average value are exempt or lightly taxed, while those of greater value are subject to a progressive tax, becoming prohibitive for palaces or estates. The tools of production should be owned by those who use them. The industrial slavery which has resulted from the passing from individual production to group production can be abolished only by group ownership. The group might be the community, but when possible it should be those who work in the factory, cultivate the farm, sail the ship, etc. The ownership and conduct of industries should be vested where the maximum economic efficiency and conditions most favorable to those who work will result. We all agree that the nation should own and manage the postoffice, the states the roads, the cities the water supply. The extension of state ownership and conduct is entirely a matter of economic efficiency and social welfare. The state should own large natural resources and enterprises, which by the nature of things are monopolies or can most advantageously be conducted as such. The nation should now conduct the telegraph and express service, probably the business of insurance; it or the states should own, but probably not conduct the railways. The states should own the mines and water power; the cities the means of transportation and illumination and the telephones; but at present they can probably be conducted most advantageously by private enterprise. Under existing conditions of human nature place must be given for competition and savings, and an official bureaucracy must be avoided.

18. *Education and research to be promoted to the limits permitted by the resources of the state.* It is the great triumph of our industrial democracy that it has supported free education as has no other nation. But we have still to learn what kind of education is of most worth and to extend it to every individual at every age. Together with the bearing and rearing of children, the greatest service to mankind is creation in science and art and their useful applications. In both cases production has been left to fundamental instincts; but these should be reinforced in all possible ways. Payment should be made for services to society no less than for services to individuals, for which only the present competitive system provides. We admit that research must be paid for by society; university chairs are given as rewards, research institutions are endowed, the government undertakes scientific work.

But we have by no means gone far enough. Abram H. Hewitt estimated that a single scientific advance—the Bessemer steel process—produces two billion dollars a year for the world. So much has not been spent on research in its whole history; but so much should be spent annually, as soon as men can be found or bred to do the work. Science has given us democracy by providing resources adequate to give each his share of education and of opportunity. Plato had to provide an aristocracy and slaves for his republic. Science by reducing to one fourth the manual work that each must do and by doubling the length of life has made democracy possible and has given us so much of it as we have. For the security and extension of political and social democracy, the advancement of science should be one of the principal concerns of a democratic government and of a democratic people.

19. *Equality of advantages to the young; equality of opportunity to all; no special privileges; individual liberty, except when this interferes with the liberty or welfare of others; so far as may be, to each all that he needs, from each all that he can give.* These are the ends which this program is intended to forward. They are the presuppositions of radical democracy and do not require argument or defense.

20. *The ends here stated to be reached only by gradual evolution and forwarded by conservative methods.* In a democracy certain individuals may be prophets or leaders, but we can not advance beyond or apart from the sentiments of the people. They as a whole are more likely to react correctly to the existing situation than any individual. It is proper and desirable that proposals shall be made and urged, however radical and revolutionary; it is equally desirable that laws shall be enacted only when they answer the demands of public opinion. A narrow majority should never enforce radical changes or unduly coerce a minority. Laws, measures and policies should as nearly as may be represent the average opinion after individuals have been counted and weighed. Revolutions are likely to keep on revolving and to be turned by cranks. There are occasions when a saturated solution may be crystallized by a shake; but we should trust to the slow processes of evolution, letting our leaders and our laws follow the moral and intellectual development of a democratic people. A government of laws is better than a government by men; but better than either is freedom, controlled by public opinion and common sense, by precedent and good will.

THE PROGRESS OF SCIENCE

CRAWFORD WILLIAMSON LONG AND THE USE OF ANESTHETICS IN SURGERY

ON March 30, 1842, in the village of Jefferson, Georgia, Dr. Crawford W. Long administered ether to Mr. James Venable and, while he was completely anesthetized, removed a small tumor from the back of his neck. On the seventieth anniversary of the day, exercises in honor of Long were held in the Medical School of the University of Pennsylvania, from which he graduated in 1839. Addresses were made by Professor J. William White, of the University of Pennsylvania, and by Professor J. Chalmers Da Costa, of the Jefferson Medical College, and a bronze medallion designed by Professor R. Tait Mackenzie, of the University of Pennsylvania, was unveiled by one of the three daughters of Dr. Long who were present at the ceremony.

Thus somewhat late official recognition has been given at the University of Pennsylvania to one of the advances in the medical sciences, which make an epoch in their development. At the close of the second of an important series of lectures on medical research, published above, Professor Richard M. Pearce, of the University of Pennsylvania, calls attention to the new era in surgery introduced by the use of anesthetics. This not only saves immeasurable suffering, but it makes possible, and comparatively safe, operations that could not be undertaken if the patient could move and struggle. Professor Pearce does not attempt to assign credit for the discovery of anesthetics, though he properly attributes its introduction to the world to the administration of ether by Dr. W. T. G. Morton, a dentist, for an operation performed by Dr. J. C. Warren at the Massachusetts General Hospital on October 16, 1846.

Like scientific progress in many other directions, the use of anesthetics has had a long history, and we must speak of various advances rather than of a single discovery. The anesthetic effects of nepenthe, mandragora and hemp were known in antiquity, and it is said that surgical operations under them were performed in the time of Pliny, in China and in the middle ages. Sir Humphry Davy in 1800 announced the discovery of the anesthetic properties of nitrous oxide, and wrote, "it may probably be used with advantage in surgical operations." Ether had been known for centuries, and in the first part of the nineteenth century its vapor and nitrous oxide gas were used for spasmodic asthma and to relieve pain. They were also used for their intoxicating effects, and it was under such conditions that Long noted their anesthetic properties.

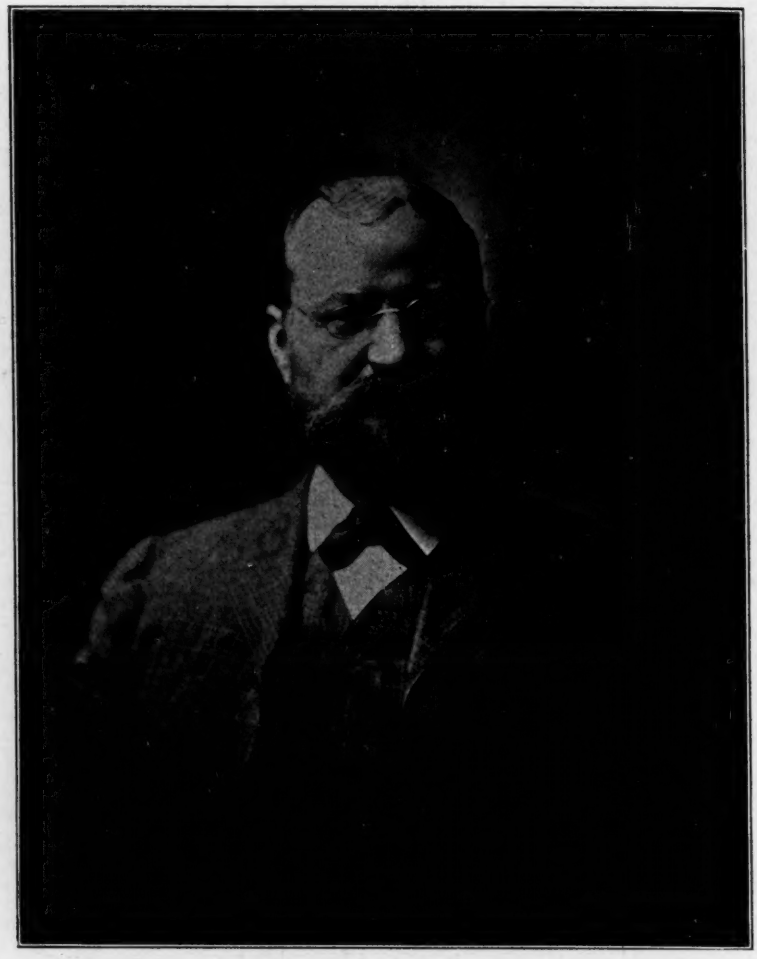
Somewhat more than two years after the operation by Long, Dr. Horace Wells, a dentist of Hartford, Conn., had a tooth extracted while rendered insensible by nitrous oxide, and two years later, as noted above, ether was used by Dr. Morton. Dr. Wells and Dr. Morton had been in partnership, and both had been pupils of Dr. C. T. Jackson, the distinguished chemist and geologist of Boston, who in 1841 had experimented with both nitrous oxide gas and with ether, using them for the relief of pain. Morton patented ether in 1846 under the name of letheon, and a bitter controversy followed, in which Jackson, Wells and Morton were involved. Wells became insane and committed suicide. Later Jackson also became insane. Morton died from apo-

BRONZE MEDALLION IN MEMORY OF CRAWFORD W. LONG.

plexy, it is said while enraged at the attempts made to deprive him of the credit of the discovery. Long took no part in these controversies, but in 1849 presented a statement to the Medical Society of Georgia, with affidavits in regard to the use of ether in 1842, followed by seven or eight surgical operations before Morton's success in introducing anesthetics everywhere. The question of priority is thus much involved, but it appears evident that Long first used ether for surgical purposes, though, as a country practitioner, he had no means of making public his discovery and perhaps did not fully realize its importance. It seems, at all events, that the use of anesthetics in surgery is one of the great advances in science which may fairly be attributed to the United States.

THE SCIENTIFIC PROGRAM OF THE AMERICAN PHILOSOPHICAL SOCIETY

THE American Philosophical Society, founded in Philadelphia by Franklin for the promotion of useful knowledge, is the oldest of our scientific societies and at the same time appears to be the most vigorous of those that cover the whole range of the sciences. The meeting held in Philadelphia at the end of April was quite notable for the number and value of the communications. They not only gave reports of important original investigations by the authors, but were in most cases presented in a manner comprehensible and interesting to those who are not specialists. It is of course impossible to give an abstract in two or three paragraphs of nearly



THE LATE JOHN BERNHARDT SMITH,
Professor of Entomology at Rutgers College and State Entomologist of New Jersey.

fifty papers, but a statement of some of the subjects may be of interest as showing the directions in which research work is now being conducted.

At the first session, papers were presented bearing on historical, political and philological subjects, for the Philosophical Society includes these also in its scope. This aspect of its work was indeed emphasized at the recent meeting, as the Henry M. Phillips prize of $2,000 was conferred on Charles H. Burr, Esq., for an essay on the treaty-making power of the United States, and at the dinner, the principal address was made by Professor Moore, who in the usual eulogy of Franklin spoke of his work in diplomacy.

On the second day, the session opened with two papers on the inheritance of feeble-mindedness and epilepsy, by Dr. Goddard and Dr. Weeks, who have obtained results of scientific and practical importance. Dr. Stockard described for the first time experiments on the control of embryonic development, showing that when guinea-pigs are alcoholized, the offspring are greatly af-

fected, and this irrespective of whether it is the male or the female that has been given alcohol. If these experiments are confirmed, it appears that the paternal germ cells may be affected so as to be incapable of producing normal offspring. Dr. Rouse gave an account of his successful attempts to isolate the active agent which produces sarcoma in chickens, which may prove a step forward in the explanation of the cause of cancer. Dr. Vaughan explained how he had split up the protein molecule and obtained a highly poisonous body, Dr. Russell the methods he had used to produce immunity to typhoid fever, and Dr. Carrel the experiments by which he had kept the heart muscle alive outside the body. Papers on botany were presented by Professor Farlow and Dr. Trelease; on paleontology, by Professor Scott and Dr. Walcott; on exploration and discovery by Professor Bingham and General Greely.

The papers in the exact sciences were as important as those in the natural sciences, and were fully as interesting, in spite of the greater difficulty of presenting such subjects before a general audience. Professor Wood gave the evening lecture before the reception, his subject being "The study of nature by invisible light." The lecture was elaborately illustrated and included his curious and beautiful photographs taken with ultra-red light. In a more technical paper, Professor Wood showed the selective reflection of gas molecules, which he has photographed. Professor Webster described his method of measuring the sound transmitted through walls; Professor Magie, the thermal relations of solutions; Dr. Day, the measurement of temperatures up to 750 degrees C., and Dr. Bauer, the results of the magnetic observations made on the yacht *Carnegie*. In astronomy, there was a symposium on stellar spectroscopy. Dr. Campbell explained the work which has been done, largely at the Lick Observatory, on radial velocity; Dr. Pickering, the important work of the Harvard Observatory on photographing the spectra of the stars. Papers of equal importance in chemistry and in other sciences were presented. Altogether they represent a group of contributions to science which will compare favorably with any that could at the present time be presented before any society in any country.

THE FOREIGN-BORN POPULATION OF NEW YORK CITY

THE Census Bureau has given out a preliminary statement of the distribution of the foreign-born population of New York in 1910. The numbers are about 2,700,000 in the state and about 1,900,000 in the city of New York, approaching in the latter case one half of the total population, and far exceeding this, if the native children born to foreign parents are included. In both New England and the middle states considerably more than half the population is of foreign parentage and the proportion is increasing with great rapidity. The distribution of the foreign-born population is of special interest. It is well known that the Russians, Italians and Austrians have been increasing far more rapidly than the Germans and Irish, but the actual figures are truly surprising. In 1850 forty-three per cent. of the foreign-born population of the United States was Irish, fourteen per cent. English, three per cent. Scotch, twenty-six per cent. German, seven per cent. Canadian, leaving only seven per cent. from all other nations. In 1900 the percentage of Germans had remained about the same, the percentage of Irish had decreased by about sixteen, and the influx from Russia, Italy and Austria Hungary had become noticeable. In the figures now given out for New York City, we find that there are 45,000 fewer Germans and 22,500 fewer Irish than there were ten years ago. On the other hand, the Italian population shows an increase of nearly 200,000, being now 340,000. New York City is now an Italian city nearly as

large as Rome and bids fair to exceed it in the course of the coming decennium. The Austria-Hungarian population has more than doubled, having increased from about 120,000 to 267,000. Greatest of all is the Russian increase, from 180,000 in 1890 to 484,000 in 1910. A citizen of New York City on being asked whether there was a foreign quarter in the city replied that there was a foreign three-quarters; and this is not far from correct.

SCIENTIFIC ITEMS

WE record with regret the death of Dr. Paul C. Freer, director of the U. S. Government Scientific Bureau in the Philippines, and distinguished for his work in chemistry; of the Rev. George William Knox, professor of philosophy and the history of religion in the Union Theological Seminary, and of Miss Nettie M. Stevens, associate in experimental morphology in Bryn Mawr College.

DR. JOHN GRIER HIBBEN, previously Stuart professor of philosophy, has been installed as president of Princeton University.—Commemoration day will be observed by the University of Glasgow on June 25, when Professor F. O. Bower, F.R.S., will deliver an oration on "Sir Joseph Hooker."—The Aero Club of Washington has held a field day in commemoration of the anniversary of Secretary Langley's first aerodrome flight on May 6, 1896.—The letters of the late Professor William James are being collected for biographical purposes. Those who have such letters are requested to communicate with Mr. Henry James, Jr., 95 Irving Street, Cambridge, Mass.

AT the meeting of the National Academy of Sciences, held in Washington on April 18, new members were elected as follows: R. W. Wood, professor of experimental physics at the Johns Hopkins University; Harry Fielding Reid, professor of geological physics at the Johns Hopkins University; David White, geologist, U. S. Geological Survey; Roland Thaxter, professor of cryptogamic botany at Harvard University; Chas. B. Davenport, director of the Station for Experimental Evolution, Cold Spring Harbor, N. Y.; W. M. Wheeler, professor of economic entomology at Harvard University; John J. Abel, professor of pharmacology at the Johns Hopkins University; S. J. Meltzer, head of the department of physiology and pharmacology of the Rockefeller Institute for Medical Research.

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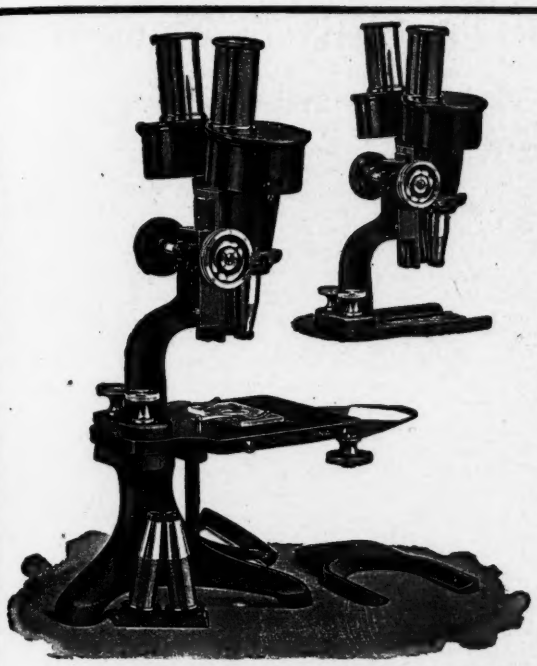

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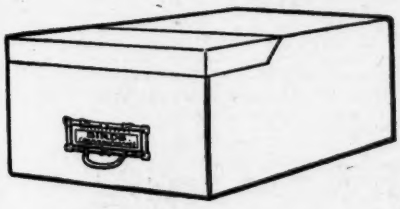

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